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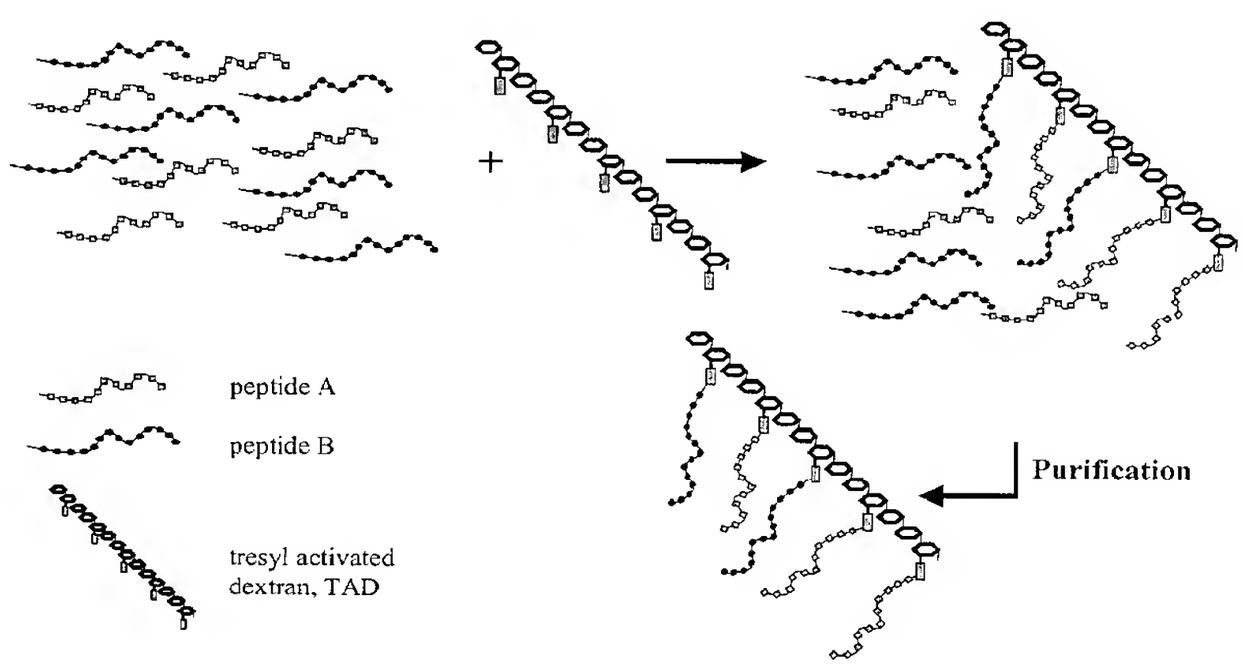
(54) Title: NOVEL METHOD FOR DOWN-REGULATION OF AMYLOID



(57) Abstract: Disclosed are novel methods for combatting diseases characterized by deposition of amyloid. The methods generally rely on immunization against amyloid precursor protein (APP) or beta amyloid (Aβ). Immunization is preferably effected by administration of analogues of autologous APP or Aβ, said analogues being capable of inducing antibody production against the autologous amyloidogenic polypeptides. Especially preferred as an immunogen is autologous Aβ which has been modified by introduction of one single or a few foreign, immunodominant and promiscuous T-cell epitopes. Also disclosed are nucleic acid vaccination against APP or Aβ and vaccination using live vaccines as well as methods and means useful for the vaccination. Such methods and means include methods for the preparation of analogues and pharmaceutical formulations, as well as nucleic acid fragments, vectors, transformed cells, polypeptides and pharmaceutical formulations.

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NOVEL METHOD FOR DOWN-REGULATION OF AMYLOID

FIELD OF THE INVENTION

The present invention relates to improvements in therapy and prevention of Alzheimer's disease (AD) and other diseases characterized by deposition of amyloid, e.g. characterized by amyloid deposits in the central nervous system (CNS). More specifically, the present invention provides a method for down-regulating (undesired) deposits of amyloid by enabling the production of antibodies against a relevant protein (APP or Aβ) or components thereof in subjects suffering from or in danger of suffering from diseases having a pathology involving amyloid deposition. The invention also provides for methods of producing polypeptides useful in this method as well as for the modified polypeptides as such. Also encompassed by the present invention are nucleic acid fragments encoding the modified polypeptides as well as vectors incorporating these nucleic acid fragments and host cells and cell lines transformed therewith. Finally, the present invention also provides for a new type of conjugate peptide immunogen.

BACKGROUND OF THE INVENTION

Amyloidosis is the extracellular deposition of insoluble protein fibrils leading to tissue damage and disease (Pepys, 1996; Tan et al., 1995; Kelly, 1996). The fibrils form when normally soluble proteins and peptides self-associate in an abnormal manner (Kelly, 1997).

Amyloid is associated with serious diseases including systemic amyloidosis, AD, maturity onset diabetes, Parkinson's disease, Huntington's disease, fronto-temporal dementia and the

prion-related transmissible spongiform encephalopathies (kuru and Creutzfeldt-Jacob disease in humans and scrapie and BSE in sheep and cattle, respectively) and the amyloid plaque formation in for instance Alzheimer's seems to be closely associated with the progression of human disease. In animal models over-expression, or the expression of modified forms, of proteins found in deposits, like the β-amyloid protein, has been shown to induce various symptoms of disease, e.g. Alzheimer's-like symptoms. There is no specific treatment for amyloid deposition and these diseases are usually fatal.

The subunits of amyloid fibrils may be wild-type, variant or truncated proteins, and similar fibrils can be formed in vitro from oligopeptides and denatured proteins (Bradbury et al., 1960; Filshie et al., 1964; Burke & Rougvie, 1972). The nature of the polypeptide component of the fibrils defines the character of the amyloidosis. Despite large differences in the size, native structure and function of amyloid proteins, all amyloid fibrils are of indeterminate length, unbranched, 70 to 120 Å in diameter, and display characteristic staining with Congo Red (Pepys, 1996). They are characteristic of a cross-β structure (Pauling & Corey, 1951) in which the polypeptide chain is organized in β-sheets. Although the amyloid proteins have very different precursor structures, they can all undergo a structural conversion, perhaps along a similar pathway, to a misfolded form that is the building block of the β-sheet helix protofilament.

This distinctive fibre pattern led to the amyloidoses being called the β-fibrilloses (Glenner, 1980a,b), and the fibril protein of AD was named the β-protein before its secondary structure was known (Glenner & Wong, 1984). The characteristic

cross-β diffraction pattern, together with the fibril appearance and tinctorial properties are now the accepted diagnostic hallmarks of amyloid, and suggest that the fibrils, although formed from quite different protein precursors, share a degree of structural similarity and comprise a structural superfamily, irrespective of the nature of their precursor proteins (Sunde M, Serpell LC, Bartlam M, Fraser PE, Pepys MB, Blake CCFJ Mol Biol 1997 Oct 31; 273(3):729-739).

One of the most widespread and well-known diseases where amyloid deposits in the central nervus system are suggested to have a central role in the progression of the disease, is AD.

AD

Alzheimer's disease (AD) is an irreversible, progressive brain disorder that occurs gradually and results in memory loss, behavioural and personality changes, and a decline in mental abilities. These losses are related to the death of brain cells and the breakdown of the connections between them. The course of this disease varies from person to person, as does the rate of decline. On average, AD patients live for 8 to 10 years after they are diagnosed, though the disease can last for up to 20 years.

AD advances by stages, from early, mild forgetfulness to a severe loss of mental function. This loss is known as dementia. In most people with AD, symptoms first appear after the age of 60, but earlier onsets are not infrequent. The earliest symptoms often include loss of recent memory, faulty judgment, and changes in personality. Often, people in the initial stages of AD think less clearly and forget the names of familiar people and common objects. Later in the disease, they may forget how to do even simple tasks. Eventually, people with AD lose all

reasoning ability and become dependent on other people for their everyday care. Ultimately, the disease becomes so debilitating that patients are bedridden and likely to develop other illnesses and infections. Most commonly, people with AD die from pneumonia.

Although the risk of developing AD increases with age, AD and dementia symptoms are not a part of normal aging. AD and other dementing disorders are caused by diseases that affect the brain. In normal aging, nerve cells in the brain are not lost in large numbers. In contrast, AD disrupts three key processes: Nerve cell communication, metabolism, and repair. This disruption ultimately causes many nerve cells to stop functioning, lose connections with other nerve cells, and die.

At first, AD destroys neurons in parts of the brain that control memory, especially in the hippocampus and related structures. As nerve cells in the hippocampus stop functioning properly, short-term memory fails, and often, a person's ability to do easy and familiar tasks begins to decline. AD also attacks the cerebral cortex, particularly the areas responsible for language and reasoning. Eventually, many other areas of the brain are involved, all these brain regions atrophy (shrink), and the AD patient becomes bedridden, incontinent, totally helpless, and unresponsive to the outside world (source: National Institute on Aging Progress Report on Alzheimer's Disease, 1999).

The Impact of AD

AD is the most common cause of dementia among people age 65 and older. It presents a major health problem because of its enormous impact on individuals, families, the health care system, and society as a whole. Scientists estimate that up to 4

million people currently suffer from the disease, and the prevalence doubles every 5 years beyond age 65. It is also estimated that approximately 360,000 new cases (incidence) will occur each year, though this number will increase as the population ages (Brookmeyer *et al.*, 1998).

AD puts a heavy economic burden on society. A recent study in the United States estimated that the annual cost of caring for one AD patient is $18,408 for a patient with mild AD, $30,096 for a patient with moderate AD, and $36,132 for a patient with severe AD. The annual national cost of caring for AD patients in the US is estimated to be slightly over $50 billion (Leon *et al.*, 1998).

Approximately 4 million Americans are 85 or older, and in most industrialized countries, this age group is one of the fastest growing segments of the population. It is estimated that this group will number nearly 8.5 million by the year 2030 in the US; some experts who study population trends suggest that the number could be even greater. As more and more people live longer, the number of people affected by diseases of aging, including AD, will continue to grow. For example, some studies show that nearly half of all people age 85 and older have some form of dementia. (National Institute on Aging Progress Report on Alzheimer's Disease, 1999)

The Main Characteristics of AD

Two abnormal structures in the brain are the hallmarks of AD: amyloid plaques and neurofibrillary tangles (NFT). Plaques are dense, largely insoluble deposits of protein and cellular material outside and around the brain's neurons. Tangles are insoluble twisted fibres that build up inside neurons.

Two types of AD exist: familial AD (FAD), which follows a certain pattern of inheritance, and sporadic AD, where no obvious pattern of inheritance is seen. Because of differences in the age at onset, AD is further described as early-onset (occurring in people younger than 65) or late-onset (occurring in those 65 and older). Early-onset AD is rare (about 10 percent of cases) and generally affects people aged 30 to 60. Some forms of early-onset AD are inherited and run in families. Early-onset AD also often progresses faster than the more common, late-onset form.

All FADs known so far have an early onset, and as many as 50 percent of FAD cases are now known to be caused by defects in three genes located on three different chromosomes. These are mutations in the APP gene on chromosome 21; mutations in a gene on chromosome 14, called presenilin 1; and mutations in a gene on chromosome 1, called presenilin 2. There is as yet no evidence, however, that any of these mutations play a major role in the more common, sporadic or non-familial form of late-onset AD. (National Institute on Aging Progress Report on Alzheimer's Disease, 1999)

Amyloid Plaques

In AD, amyloid plaques develop first in areas of the brain used for memory and other cognitive functions. They consist of largely insoluble deposits of beta amyloid (hereinafter designated Aβ) - a protein fragment of a larger protein called amyloid precursor protein (APP, the amino acid sequence of which is set forth in SEQ ID NO: 2) - intermingled with portions of neurons and with non-nerve cells such as microglia and astrocytes. It is not known whether amyloid plaques themselves constitute the main cause of AD or whether they are a

by-product of the AD process. Certainly, changes in the APP protein can cause AD, as shown in the inherited form of AD caused by mutations in the APP gene, and Aβ plaque formation seems to be closely associated with the progression of the human disease (Lippa C. F. *et al.* 1998).

APP

APP is one of many proteins that are associated with cell membranes. After it is made, APP becomes embedded in the nerve cell's membrane, partly inside and partly outside the cell. Recent studies using transgenic mice demonstrate that APP appears to play an important role in the growth and survival of neurons. For example, certain forms and amounts of APP may protect neurons against both short- and long-term damage and may render damaged neurons better able to repair themselves and help parts of neurons grow after brain injury.

While APP is embedded in the cell membrane, proteases act on particular sites in APP, cleaving it into protein fragments. One protease helps cleave APP to form Aβ, and another protease cleaves APP in the middle of the amyloid fragment so that Aβ cannot be formed. The Aβ formed is of two different lengths, a shorter 40 (or 41) amino acids Aβ that is relatively soluble and aggregates slowly, and a slightly longer, 42 amino acids "sticky" Aβ that rapidly forms insoluble clumps. While Aβ is being formed, it is not yet known exactly how it moves through or around nerve cells. In the final stages of this process, the "sticky" Aβ aggregates into long filaments outside the cell and, along with fragments of dead and dying neurons and the microglia and astrocytes, forms the plaques that are characteristic of AD in brain tissue.

Some evidence exists that the mutations in APP render more likely that Aβ will be snipped out of the APP precursor, thus causing either more total Aβ or relatively more of the "sticky" form to be made. It also appears that mutations in the presenilin genes may contribute to the degeneration of neurons in at least two ways: By modifying Aβ production or by triggering the death of cells more directly. Other researchers suggest that mutated presenilins 1 and 2 may be involved in accelerating the pace of apoptosis.

It is to be expected that as the disease progresses, more and more plaques will be formed, filling more and more of the brain. Studies suggest that it may be that the Aβ is aggregating and disaggregating at the same time, in a sort of dynamic equilibrium. This raises the hope that it may be possible to break down the plaques even after they have formed. (National Institute on Aging Progress Report on Alzheimer's Disease, 1999).

It is believed that Aβ is toxic to neurons. In tissue culture studies, researchers observed an increase in death of hippocampal neurons cells engineered to over-express mutated forms of human APP compared to neurons over-expressing the normal human APP (Luo *et al.*, 1999).

Furthermore, overexpression or the expression of modified forms of the Aβ protein has in animal models been demonstrated to induce Alzheimer-like symptoms, (Hsiao K. *et al.*, 1998)

Given that increased Aβ generation, its aggregation into plaques, and the resulting neurotoxicity may lead to AD, it is of therapeutic interest to investigate conditions under which Aβ aggregation into plaques might be slowed down or even blocked.

Presenilins

Mutations in presenilin-1 (S-180) account for almost 50% of all cases of early-onset familial AD (FAD). Around 30 mutations have been identified that give rise to AD. The onset of AD varies with the mutations. Mutations in presenilin-2 account for a much smaller part of the cases of FAD, but is still a significant factor. It is not known whether presenilins are involved in sporadic non-familial AD. The function of the presenilins is not known, but they appear to be involved in the processing of APP to give Aβ-42 (the longer stickier form of the peptide, SEQ ID NO: 2, residues 673-714), since AD patients with presenilin mutations have increased levels of this peptide. It is unclear whether the presenilins also have a role in causing the generation of NFT's. Some suggest that presenilins could also have a more direct role in the degeneration of neurons and neuron death. Presenilin-1 is located at chromosome 14 while presenilin-2 is linked to chromosome 1. If a person harbours a mutated version of just one of these genes he or she is almost certain to develop early onset AD.

There is some uncertainty to whether presenilin-1 is identical to the hypothetical gamma-secretase involved in the processing of APP (Naruse et al., 1998).

Apolipoprotein E

Apolipoprotein E is usually associated with cholesterol, but is also found in plaques and tangles of AD brains. While alleles 1-3 do not seem to be involved in AD there is a significant correlation between the presence of the APOE-ε4 allele and development of late AD (Strittmatter et al., 1993). It is, however, a risk factor and not a direct cause as is the case

for the presenilin and APP mutations and it is not limited to familial AD.

The ways in which the ApoE ε4 protein increases the likelihood of developing AD are not known with certainty, but one possible theory is that it facilitates Aβ buildup and this contributes to lowering the age of onset of AD, or the presence or absence of particular APOE alleles may affect the way neurons respond to injury (Buttini et al., 1999).

Also Apo A1 has been shown to be amyloigenic. Intact apo A1 can itself form amyloid-like fibrils *in vitro* that are Congo red positive (Am J Pathol 147 (2): 238-244 (Aug 1995), Wisniewski T, Golabek AA, Kida E, Wisniewski KE, Frangione B).

There seem to be some contradictory results indicating that there is a positive effect of the APOE-ε4 allele in decreasing symptoms of mental loss, compared to other alleles (Stern, Brandt, 1997, Annals of Neurology 41).

Neurofibrillary Tangles

This second hallmark of AD consists of abnormal collections of twisted threads found inside nerve cells. The chief component of tangles is one form of a protein called tau (τ). In the central nervous system, tau proteins are best known for their ability to bind and help stabilize microtubules, which are one constituent of the cell's internal support structure, or skeleton. However, in AD tau is changed chemically, and this altered tau can no longer stabilize the microtubules, causing them to fall disintegrate. This collapse of the transport system may at first result in malfunctions in communication between nerve cells and may later lead to neuronal death.

In AD, chemically altered tau twists into paired helical filaments - two threads of tau that are wound around each other. These filaments are the major substance found in neurofibrillary tangles. In one recent study, researchers found neurofibrillary changes in fewer than 6 percent of the neurons in a particular part of the hippocampus in healthy brains, in more than 43 percent of these neurons in people who died with mild AD, and in 71 percent of these neurons in people who died with severe AD. When the loss of neurons was studied, a similar progression was found. Evidence of this type supports the idea that the formation of tangles and the loss of neurons progress together over the course of AD. (National Institute on Aging Progress Report on Alzheimer's Disease, 1999).

Tauopathies and Tangles

Several neurodegenerative diseases, other than AD, are characterized by the aggregation of tau into insoluble filaments in neurons and glia, leading to dysfunction and death. Very recently, several groups of researchers, who were studying families with a variety of hereditary dementias other than AD, found the first mutations in the tau gene on chromosome 17 (Clark *et al.*, 1998; Hutton *et al.*, 1998; Poorkaj *et al.*, 1998; Spillantini *et al.*, 1998). In these families, mutations in the tau gene cause neuronal cell death and dementia. These disorders which share some characteristics with AD but differ in several important respects, are collectively called "fronto temporal dementia and parkinsonism linked to chromosome 17" (FTDP-17). They are diseases such as Parkinson's disease, some forms of amyotrophic lateral sclerosis (ALS), corticobasal degeneration, progressive supranuclear palsy, and Pick's disease, and are all characterized by abnormal aggregation of tau protein.

Other AD-like neurological diseases.

There are important parallels between AD and other neurological diseases, including prion diseases (such as kuru, Creutzfeld-Jacob disease and bovine spongiform encephalitis), Parkinson's disease, Huntington's disease, and fronto-temporal dementia. All involve deposits of abnormal proteins in the brain. AD and prion diseases cause dementia and death, and both are associated with the formation of insoluble amyloid fibrils, but from membrane proteins that are different from each other.

Scientists studying Parkinson's disease, the second most common neurodegenerative disorder after AD, discovered the first gene linked to the disease. This gene codes for a protein called synuclein, which, intriguingly, is also found in the amyloid plaques of AD patients' brains (Lavedan C, 1998, Genome Res. 8(9): 871-80). Investigators have also discovered that genetic defects in Huntington's disease, another progressive neurodegenerative disorder that causes dementia, cause the Huntington protein to form into insoluble fibrils very similar to the Aβ fibrils of AD and the protein fibrils of prion disease, (Scherzinger E, *et al.*, 1999, PNAS U.S.A. 96(8): 4604-9).

Scientists have also discovered a novel gene, which when mutated, is responsible for familial British dementia (FBD), a rare inherited disease that causes severe movement disorders and progressive dementia similar to that seen in AD. In a biochemical analysis of the amyloid fibrils found in the FBD plaques, a unique peptide named ABri was found (Vidal *et al.*, 1999). A mutation at a particular point along this gene results in the production of a longer-than-normal Bri protein.

The ABri peptide, which is snipped from the mutated end of the Bri protein is deposited as amyloid fibrils. These plaques are thought to lead to the neuronal dysfunction and dementia that characterizes FBD.

Immunization with Aβ

The immune system will normally take part in the clearing of foreign protein and proteinaceous particles in the organism but the deposits associated with the above-mentioned diseases consist mainly of self-proteins, thereby rendering the role of the immune system in the control of these diseases less obvious. Further, the deposits are located in a compartment (the CNS) normally separated from the immune system, both facts suggesting that any vaccine or immunotherapeutical approach would be unsuccessful.

Nevertheless, scientists have recently attempted immunizing mice with a vaccine composed of heterologous human Aβ and a substance known to excite the immune system (Schenk *et al.*, 1999 and WO 99/27944). The vaccine was tested in a partial transgenic mouse model of AD with a human mutated gene for APP inserted into the DNA of the mouse. The mice produced the modified APP protein and developed amyloid plaques as they grew older. This mouse model was used to test whether vaccination against the modified transgenic *human* APP had an effect on plaque build-up. In a first experiment, one group of transgenic mice was given monthly injections of the vaccine starting at 6 weeks of age and ending at 11 months. A second group of transgenic mice received no injections and served as a control group. By 13 months of age, the mice in the control group had plaques covering 2 to 6 percent of their brains. In contrast, the immunized mice had virtually no plaques.

In a second experiment, the researchers began the injections at 11 months, when some plaques had already developed. Over a 7-month period, the control transgenic mice had a 17-fold increase in the amount of plaque in their brains, whereas those who received the vaccine had a 99-percent decrease compared to the 18-month-old control transgenic mice. In some mice, some of the pre-existing plaque deposits appeared to have been removed by the treatment. It was also found that other plaque-associated damage, such as inflammation and abnormal nerve cell processes, lessened as a result of the immunization.

The above is thus a preliminary study in mice and for example, scientists need to find out whether vaccinated mice remain healthy in other respects and whether memory of those vaccinated remains normal. Furthermore, because the mouse model is not a complete representation of AD (the animals do not develop neurofibrillary tangles nor do many of their neurons die), additional studies will be necessary to determine whether humans have a similar or different reaction from mice. Another issue to consider is that the method may perhaps "cure" amyloid deposition but fail to stop development of dementia.

Technical issues present major challenges as well. For example it is unlikely that it is even possible, using this technology, to create a vaccine which enables humans to raise antibodies against their own proteins. So numerous issues of safety and effectiveness will need to be resolved before any tests in humans can be considered.

The work by Schenk *et al.* thus shows that if it was possible to generate a strong immune response towards self-proteins in

proteinaceous deposits in the central nervus system such as the plaques formed in AD, it is possible to both prevent the formation of the deposits and possibly also clear already formed plaques.

Recently, clinical trials using the above-discussed Aβ vaccines have been terminated due to adverse effects: A number of the vaccinated subjects developed chronic encephalitis that may be due to an uncontrolled autoimmunity against Aβ in the CNS.

OBJECT OF THE INVENTION

The object of the present invention is to provide novel therapies against conditions characterized by deposition of amyloid, such as AD. A further object is to develop an autovaccine against amyloid, in order to obtain a novel treatment for AD and for other pathological disorders involving amyloid deposition.

SUMMARY OF THE INVENTION

Described herein is the use of an autovaccination technology for generating strong immune responses against otherwise non-immunogenic APP and Aβ Described is also the preparation of such vaccines for the prevention, possible cure or alleviation of the symptoms of such diseases associated with amyloid deposits.

Thus, in its broadest and most general scope, the present invention relates to a method for *in vivo* down-regulation of

amyloid precursor protein (APP) or beta amyloid (Aβ) in an animal, including a human being, the method comprising effecting presentation to the animal's immune system of an immunogenically effective amount of at least one analogue of APP or Aβ that incorporates into the same molecule at least one B-cell epitope of APP and/or Aβ and at least one foreign T-helper epitope (T_H epitope) so that immunization of the animal with the analogue induces production of antibodies against the animal's autologous APP or Aβ, wherein the analogue

a) is a polyamino acid that consists of at least one copy of a subsequence of residues 672-714 in SEQ ID NO: 2, wherein the foreign T_H epitope is incorporated by means of amino acid addition and/or insertion and/or deletion and/or substitution, wherein the subsequence is selected from the group consisting of residues 1-42, residues 1-40, residues 1-39, residues 1-35, residues 1-34, residues 1-28, residues 1-12, residues 1-5, residues 13-28, residues 13-35, residues 17-28, residues 25-35, residues 35-40, residues 36-42 and residues 35-42 of the amino acid sequence consisting of amino acid residues 673-714 of SEQ ID NO: 2; and/or

b) is a polyamino acid that contains the foreign T_H epitopes and a disrupted APP or Aβ sequence so that the analogue does not include any subsequence of SEQ ID NO: 2 that binds productively to MHC class II molecules initiating a T-cell response; and/or

c) is a polyamino acid that comprises the foreign T_H epitope and APP or Aβ derived amino acids, and comprises 1 single methionine residue located in the C-terminus of the analogue, wherein other methionine residues in APP

or Aβ and in the foreign T_H epitope have been substituted or deleted, and preferably have been substituted by leucin or isoleucine; and/or

d) is a conjugate comprising a polyhydroxypolymer backbone to which is separately coupled a polyamino acid as defined in a) and/or a polyamino acid as defined in b) and/or a polyamino acid as defined in c); and/or

e) is a conjugate comprising a polyhydroxypolymer backbone to which is separately coupled 1) the foreign T_H epitope and 2) a polyamino acid selected from the group consisting of a subsequence as defined in a), a disrupted sequence of APP or Aβ as defined in b), and an APP or Aβ derived amino acid sequence that comprises 1 single methionine residue located in the C-terminus, wherein other methionine residues in APP or Aβ and in the foreign T_H epitope have been substituted or deleted, and preferably have been substituted by leucin or isoleucine.

The present assignee has previously filed an international patent application directed to safe vaccination strategies against amyloidogenic polypeptides such as APP and Aβ, cf. WO 01/62284. This application was not published on the filing date of the present application and further does not contain details concerning the above-mentioned useful analogues of APP and Aβ.

The invention also relates to analogues of the APP and Aβ as well as to nucleic acid fragments encoding a subset of these. Also immunogenic compositions comprising the analogues or the nucleic acid fragments are part of the invention.

LEGEND TO THE FIGURE

Fig. 1: Schematic depiction of Autovac variants derived from the amyloid precursor protein with the purpose of generating antibody responses against the Aβ protein Aβ-43 (or C-100). The APP is shown schematically at the top of the figure and the remaining schematic constructs show that the model epitopes P2 and P30 are substituted or inserted into various truncations of APP. In the figure, the black pattern indicates the APP signal sequence, two-way cross-hatching is the extracellular part of APP, dark vertical hatching is the transmembrane domain of APP, light vertical hatching is the intracellular domain of APP, coarse cross-hatching indicates the P30 epitope, and fine cross-hatching indicates the P2 epitope. The full line box indicates Aβ-42/43 and the full-line box and the dotted line box together indicate C-100. "Abeta" denotes Aβ.

Fig. 2: Schematic depiction of an embodiment of the synthesis of generally applicable immunogenic conjugates. Peptide A (any antigenic sequence, e.g. an Aβ sequence described herein) and peptide B (an amino acid sequence including a foreign T-helper epitope are synthesized and mixed. After that they are contacted with a suitable activated polyhydroxypolymer, peptides A and B are attached via the activation group in a ration corresponding to the initial ratio between these two substances in the peptide mixture. Cf. Example 4 for details.

DETAILED DISCLOSURE OF THE INVENTION

Definitions

In the following a number of terms used in the present specification and claims will be defined and explained in de-

tail in order to clarify the metes and bounds of the invention.

The terms "amyloid" and "amyloid protein" which are used interchangeably herein denote a class of proteinaceous unbranched fibrils of indeterminate length. Amyloid fibrils display characteristic staining with Congo Red and share a cross-β structure in which the polypeptide chain is organized in β-sheets. Amyloid is generally derived from amyloidogenic proteins which have very different precursor structures but which can all undergo a structural conversion to a misfolded form that is the building block of the β-sheet helix protofilament. Normally, the diameter of amyloid fibrils varies between about 70 to about 120 Å.

The term "amyloidogenic protein" is intended to denote a polypeptide which is involved in the formation of amyloid deposits, either by being part of the deposits as such or by being part of the biosynthetic pathway leading to the formation of the deposits. Hence, examples of amyloidogenic proteins are APP and Aβ, but also proteins involved in the metabolism of these may be amyloidogenic proteins.

An "amyloid polypeptide" is herein intended to denote polypeptides comprising the amino acid sequence of the above-discussed amyloidogenic proteins derived from humans or other mammals (or truncates thereof sharing a substantial amount of B-cell epitopes with an intact amyloidogenic protein) - an amyloidogenic polypeptide can therefore e.g. comprise substantial parts of a precursor for the amyloidogenic polypeptide (in the case of Aβ, one possible amyloid polypeptide could be APP derived). Also unglycosylated forms of amyloidogenic polypeptides which are prepared in prokaryotic system are included

within the boundaries of the term as are forms having varying glycosylation patterns due to the use of e.g. yeasts or other non-mammalian eukaryotic expression systems. It should, however, be noted that when using the term "an amyloidogenic polypeptide" it is intended that the polypeptide in question is normally non-immunogenic when presented to the animal to be treated. In other words, the amyloidogenic polypeptide is a self-protein or is an analogue of such a self-protein which will not normally give rise to an immune response against the amyloidogenic of the animal in question.

An "analogue" is an APP or Aβ derived molecule that incorporates one or several changes in its molecular structure. Such a change can e.g. be in the form of fusion of APP or Aβ polyamino acids to a suitable fusion partner (*i*.e. a change in primary structure exclusively involving C- and/or N-terminal additions of amino acid residues) and/or it can be in the form of insertions and/or deletions and/or substitutions in the polypeptide's amino acid sequence. Also encompassed by the term are derivatized APP or Aβ derived molecules, cf. the discussion below of modifications of APP or Aβ. In some cases the analogue may be constructed so as to be less able or even unable to elicit antibodies against the normal precursor protein(s) of the amyloid, thereby avoiding undesired interference with the (physiologically normal) non-aggregated form of the polypeptide being a precursor of the amyloid protein.

It should be noted that the use as a vaccine in a human of a xeno-analogue (e.g. a canine or porcine analogue) of a human APP or Aβcan be imagined to produce the desired immunity against the APP or Aβ. Such use of an xeno-analogue for immunization is also considered part of the invention.

The term "polypeptide" is in the present context intended to mean both short peptides of from 2 to 10 amino acid residues, oligopeptides of from 11 to 100 amino acid residues, and polypeptides of more than 100 amino acid residues. Furthermore, the term is also intended to include proteins, *i.e.* functional biomolecules comprising at least one polypeptide; when comprising at least two polypeptides, these may form complexes, be covalently linked, or may be non-covalently linked. The polypeptide(s) in a protein can be glycosylated and/or lipidated and/or comprise prosthetic groups. Also, the term "polyamino acid" is an equivalent to the term "polypeptide"

The terms "T-lymphocyte" and "T-cell" will be used interchangeably for lymphocytes of thymic origin which are responsible for various cell mediated immune responses as well as for helper activity in the humoral immune response. Likewise, the terms "B-lymphocyte" and "B-cell" will be used interchangeably for antibody-producing lymphocytes.

The term "subsequence" means any consecutive stretch of at least 3 amino acids or, when relevant, of at least 3 nucleotides, derived directly from a naturally occurring amyloid amino acid sequence or nucleic acid sequence, respectively.

The term "animal" is in the present context in general intended to denote an animal species (preferably mammalian), such as *Homo sapiens*, *Canis domesticus*, etc. and not just one single animal. However, the term also denotes a population of such an animal species, since it is important that the individuals immunized according to the method of the invention all harbour substantially the same APP or Aβ allowing for immunization of the animals with the same immunogen(s). It will be clear to the skilled person that an animal in the present con-

text is a living being which has an immune system. It is preferred that the animal is a vertebrate, such as a mammal.

By the term "*in vivo* down-regulation of APP or Aβ" is herein meant reduction in the living organism of the total amount of deposited amyloid protein (or amyloid as such) of the relevant type. The down-regulation can be obtained by means of several mechanisms: Of these, simple interference with amyloid by antibody binding so as to prevent misaggregation is the most simple. However, it is also within the scope of the present invention that the antibody binding results in removal of amyloid by scavenger cells (such as macrophages and other phagocytic cells) and that the antibodies interfer with other amyloidogenic polypeptides which lead to amyloid formation. A further possibility is that antibodies bind Aβ outside the CNS, thereby effectively removing Aβ from the CNS via a simple mass action principle.

The expression "effecting presentation ... to the immune system" is intended to denote that the animal's immune system is subjected to an immunogenic challenge in a controlled manner. As will appear from the disclosure below, such challenge of the immune system can be effected in a number of ways of which the most important are vaccination with polypeptide containing "pharmaccines" (*i.e.* a vaccine which is administered to treat or ameliorate ongoing disease) or nucleic acid "pharmaccine" vaccination. The important result to achieve is that immune competent cells in the animal are confronted with the antigen in an immunologically effective manner, whereas the precise mode of achieving this result is of less importance to the inventive idea underlying the present invention.

The term "immunogenically effective amount" has its usual meaning in the art, *i.e.* an amount of an immunogen, which is capable of inducing an immune response that significantly engages pathogenic agents sharing immunological features with the immunogen.

When using the expression that the APP or Aβ has been "modified" is herein meant that a chemical modification of the polypeptide has been performed on APP or Aβ. Such a modification can e.g. be derivatization (e.g. alkylation) of certain amino acid residues in the sequence, but as will be appreciated from the disclosure below, the preferred modifications comprise changes of the primary structure of the amino acid sequence.

When discussing "autotolerance towards APP or Aβ" it is understood that since the polypeptide is a self-protein in the population to be vaccinated, normal individuals in the population do not mount an immune response against the polypeptide; it cannot be excluded, though, that occasional individuals in an animal population might be able to produce antibodies against the native polypeptide, e.g. as part of an autoimmune disorder. At any rate, an animal will normally only be autotolerant towards its own APP or Aβ, but it cannot be excluded that analogues derived from other animal species or from a population having a different phenotype would also be tolerated by said animal.

A "foreign T-cell epitope" (or: "foreign T-lymphocyte epitope") is a peptide which is able to bind to an MHC molecule and which stimulates T-cells in an animal species. Preferred foreign T-cell epitopes in the invention are "promiscuous" epitopes, *i.e.* epitopes which bind to a substantial fraction

of a particular class of MHC molecules in an animal species or population. Only a very limited number of such promiscuous T-cell epitopes are known, and they will be discussed in detail below. Promiscuous T-cell epitopes are also denoted "universal" T-cell epitopes. It should be noted that in order for the immunogens which are used according to the present invention to be effective in as large a fraction of an animal population as possible, it may be necessary to 1) insert several foreign T-cell epitopes in the same analogue or 2) prepare several analogues wherein each analogue has a different promiscuous epitope inserted. It should be noted also that the concept of foreign T-cell epitopes also encompasses use of cryptic T-cell epitopes, *i.e.* epitopes which are derived from a self-protein and which only exerts immunogenic behaviour when existing in isolated form without being part of the self-protein in question.

A "foreign T helper lymphocyte epitope" (a foreign T_H epitope) is a foreign T cell epitope, which binds an MHC Class II molecule and can be presented on the surface of an antigen presenting cell (APC) bound to the MHC Class II molecule.

A "functional part" of a (bio)molecule is in the present context intended to mean the part of the molecule which is responsible for at least one of the biochemical or physiological effects exerted by the molecule. It is well-known in the art that many enzymes and other effector molecules have an active site which is responsible for the effects exerted by the molecule in question. Other parts of the molecule may serve a stabilizing or solubility enhancing purpose and can therefore be left out if these purposes are not of relevance in the context of a certain embodiment of the present invention. For instance it is possible to use certain cytokines as a modifying moiety

in APP or Aβ (cf. the detailed discussion below), and in such a case, the issue of stability may be irrelevant since the coupling to the APP or Aβmay provide the stability necessary.

The term "adjuvant" has its usual meaning in the art of vaccine technology, *i.e.* a substance or a composition of matter which is 1) not in itself capable of mounting a specific immune response against the immunogen of the vaccine, but which is 2) nevertheless capable of enhancing the immune response against the immunogen. Or, in other words, vaccination with the adjuvant alone does not provide an immune response against the immunogen, vaccination with the immunogen may or may not give rise to an immune response against the immunogen, but the combined vaccination with immunogen and adjuvant induces an immune response against the immunogen which is stronger than that induced by the immunogen alone.

"Targeting" of a molecule is in the present context intended to denote the situation where a molecule upon introduction in the animal will appear preferentially in certain tissue(s) or will be preferentially associated with certain cells or cell types. The effect can be accomplished in a number of ways including formulation of the molecule in composition facilitating targeting or by introduction in the molecule of groups, which facilitate targeting. These issues will be discussed in detail below.

"Stimulation of the immune system" means that a substance or composition of matter exhibits a general, non-specific immunostimulatory effect. A number of adjuvants and putative adjuvants (such as certain cytokines) share the ability to stimulate the immune system. The result of using an immunostimulating agent is an increased "alertness" of the immune system

meaning that simultaneous or subsequent immunization with an immunogen induces a significantly more effective immune response compared to isolated use of the immunogen.

"Productive binding" means binding of a peptide to the MHC molecule (Class I or II) so as to be able to stimulate T-cells that engage a cell that present the peptide bound to the MHC molecule. For instance, a peptide bound to an MHC Class II molecule on the surface of an APC is said to be productively bound if this APC will stimulate a T_H cell that binds to the presented peptide-MHC Class II complex.

Preferred embodiments of amyloid down-regulation

It is preferred that the analogue used as an immunogen in the method of the invention is a modified APP or Aβ molecule wherein at least one change is present in the amino acid sequence of the APP or Aβ, since the chances of obtaining the all-important breaking of autotolerance is greatly facilitated that way - this is e.g. evident from the results presented in Example 2 herein, where immunization with wild-type Aβ is compared to immunization with an Aβ variant molecule. It has been shown (in Dalum I *et al.*, 1996, J. Immunol. **157**: 4796-4804) that potentially self-reactive B-lymphocytes recognizing self-proteins are physiologically present in normal individuals. However, in order for these B-lymphocytes to be induced to actually produce antibodies reactive with the relevant self-proteins, assistance is needed from cytokine producing T-helper lymphocytes (T_H-cells or T_H-lymphocytes). Normally this help is not provided because T-lymphocytes in general do not recognize T-cell epitopes derived from self-proteins when presented by antigen presenting cells (APCs). However, by providing an element of "foreignness" in a self-protein (*i.e.* by introducing

an immunologically significant modification), T-cells recognizing the foreign element are activated upon recognizing the foreign epitope on an APC (such as, initially, a mononuclear cell). Polyclonal B-lymphocytes (which are also APCs) capable of recognising self-epitopes on the modified self-protein also internalise the antigen and subsequently presents the foreign T-cell epitope(s) thereof, and the activated T-lymphocytes subsequently provide cytokine help to these self-reactive polyclonal B-lymphocytes. Since the antibodies produced by these polyclonal B-lymphocytes are reactive with different epitopes on the modified polypeptide, including those which are also present in the native polypeptide, an antibody cross-reactive with the non-modified self-protein is induced. In conclusion, the T-lymphocytes can be led to act as if the population of polyclonal B-lymphocytes have recognised an entirely foreign antigen, whereas in fact only the inserted epitope(s) is/are foreign to the host. In this way, antibodies capable of *cross-reacting* with non-modified self-antigens are induced.

Several ways of modifying a peptide self-antigen in order to obtain breaking of autotolerance are known in the art. It is nevertheless preferred that the analogue according to the present invention includes

- at least one first moiety is introduced which effects targeting of the modified molecule to an antigen presenting cell (APC), and/or

- at least one second moiety is introduced which stimulates the immune system, and/or

- at least one third moiety is introduced which optimizes presentation of the analogue to the immune system.

However, all these modifications should be carried out while maintaining a substantial fraction of the original B-lymphocyte epitopes in the APP or Aβ, since the B-lymphocyte recognition of the native molecule is thereby enhanced.

In one preferred embodiment, side groups (in the form of the foreign T-cell epitopes or the above-mentioned first, second and third moieties) are covalently or non-covalently introduced. This is to mean that stretches of amino acid residues derived from the APP or Aβ are derivatized without altering the primary amino acid sequence, or at least without introducing changes in the peptide bonds between the individual amino acids in the chain.

An alternative, and preferred, embodiment utilises amino acid substitution and/or deletion and/or insertion and/or addition (which may be effected by recombinant means or by means of peptide synthesis; modifications which involves longer stretches of amino acids can give rise to fusion polypeptides). One especially preferred version of this embodiment is the technique described in WO 95/05849, which discloses a method for down-regulating self-proteins by immunising with analogues of the self-proteins wherein a number of amino acid sequence(s) has been substituted with a corresponding number of amino acid sequence(s) which each comprise a foreign immunodominant T-cell epitope, while at the same time maintaining the overall tertiary structure of the self-protein in the analogue. For the purposes of the present invention, it is however sufficient if the modification (be it an insertion, addition, deletion or substitution) gives rise to a foreign T-cell epitope and at the same time preserves a substantial number of the B-cell epitopes in the APP or Aβ. However, in order to obtain maximum efficacy of the immune response induced, it is

preferred that the overall tertiary structure of the APP or Aβ is maintained in the modified molecule.

In some cases, it is preferred that the APP or Aβ or fragments thereof are mutated. Especially preferred are substitution variants where the methionine in position 35 in Aβ-43 has been substituted, preferably with leucine or isoleucine, or simply deleted. Especially preferred analogues contain one single methionine that is located in the C-terminus, either because it is naturally occurring in the amyloidogenic polypeptide or foreign T_H epitope, or because it has been inserted or added. Hence, it also preferred that the part of the analogue that includes the foreign T_H epitope is free from methionine, except from the possible C-terminal location of a methionine.

The main reason for removing all but one methionine is that it becomes possible to recombinantly prepare multimeric analogues that can be subsequently cleaved by cyanogenbromide to leave the single analogues. The advantage is, that recombinant production becomes facilitated this way.

In fact, it is generally preferred that all analogues of APP or Aβ that are used according to the present invention share the characteristic of merely including one single methionine that is positioned as the C-terminal amino acid in the analogue and that other methionines in either the amyloidogenic polypeptide or the foreign T_H epitope are deleted or substituted for another amino acid.

One further interesting mutation is a deletion or substitution of the phenylalanine in position 19 in Aβ-43, and it is especially preferred that the mutation is a substitution of this phenylalanine residue with a proline.

Other interesting polyamino acids to be used in the analogues are truncated parts of the Aβ-43 protein. These can also be employed in immunogenic analogues according to the present invention. Especially preferred are the truncates Aβ(1-42), Aβ(1-40), Aβ(1-39), Aβ(1-35), Aβ(1-34), Aβ(1-34), Aβ(1-28), Aβ(1-12), Aβ(1-5), Aβ(13-28), Aβ(13-35), Aβ(17-28), Aβ(25-35), Aβ(35-40), Aβ(36-42), and Aβ(35-42) (where the numbers in the parentheses indicate the amino acid stretches of Aβ-43 that constitute the relevant fragment - Aβ(35-40) is e.g. identical to amino acids 706-711 in SEQ ID NO: 2). All these variants with truncated parts of Aβ-43 can be made with the Aβ fragments described herein, in particular with variants 9, 10, 11, 12, and 13 mentioned in Example 1.

The following formula describes the molecular constructs generally covered by the invention:

$$(MOD_1)_{s1}(amyloid_{e1})_{n1}(MOD_2)_{s2}(amyloid_{e2})_{n2}....(MOD_x)_{sx}(amyloid_{ex})_{nx} \quad (I)$$

-where $amyloid_{e1}$-$amyloid_{ex}$ are x B-cell epitope containing subsequences of APP or Aβ which independently are identical or non-identical and which may contain or not contain foreign side groups, x is an integer ≥ 3, n1-nx are x integers ≥ 0 (at least one is ≥ 1), MOD_1-MOD_x are x modifications introduced between the preserved B-cell epitopes, and s_1-s_x are x integers ≥ 0 (at least one is ≥ 1 if no side groups are introduced in the $amyloid_{ex}$ sequences). Thus, given the general functional restraints on the immunogenicity of the constructs, the invention allows for all kinds of permutations of the original sequence of the APP or Aβ, and all kinds of modifications therein. Thus, included in the invention are modified APP or Aβ obtained by omission of parts of the sequence which e.g. ex-

hibit adverse effects *in vivo* or omission of parts which are normally intracellular and thus could give rise to undesired immunological reactions.

One preferred version of the constructs outlined above are, when applicable, those where the B-cell epitope containing subsequence of an amyloid protein is not extracellularly exposed in the precursor polypeptide from which the amyloid is derived. By making such a choice of the epitopes, it is ensured that antibodies are not generated which would be reactive with the cells producing the precursor and thereby the immune response which is generated becomes limited to an immune response against the undesired amyloid deposits. In this case it will e.g. be feasible to induce immunity against epitopes of APP or Aβ which are only exposed to the extracellular phase when being free from any coupling to the cells from which they are produced.

Maintenance of a substantial fraction of B-cell epitopes or even the overall tertiary structure of a protein which is subjected to modification as described herein can be achieved in several ways. One is simply to prepare a polyclonal antiserum directed against the polypeptide in question (e.g. an antiserum prepared in a rabbit) and thereafter use this antiserum as a test reagent (e.g. in a competitive ELISA) against the modified proteins which are produced. Modified versions (analogues) which react to the same extent with the antiserum as does the APP or Aβ must be regarded as having the same overall tertiary structure as APP or Aβ whereas analogues exhibiting a limited (but still significant and specific) reactivity with such an antiserum are regarded as having maintained a substantial fraction of the original B-cell epitopes.

Alternatively, a selection of monoclonal antibodies reactive with distinct epitopes on the APP or Aβ can be prepared and used as a test panel. This approach has the advantage of allowing 1) an epitope mapping of the APP or Aβ and 2) a mapping of the epitopes which are maintained in the analogues prepared.

Of course, a third approach would be to resolve the 3-dimensional structure of the APP or Aβ or of a biologically active truncate thereof (cf. above) and compare this to the resolved three-dimensional structure of the analogues prepared. Three-dimensional structure can be resolved by the aid of X-ray diffraction studies and NMR-spectroscopy. Further information relating to the tertiary structure can to some extent be obtained from circular dichroism studies which have the advantage of merely requiring the polypeptide in pure form (whereas X-ray diffraction requires the provision of crystallized polypeptide and NMR requires the provision of isotopic variants of the polypeptide) in order to provide useful information about the tertiary structure of a given molecule. However, ultimately X-ray diffraction and/or NMR are necessary to obtain conclusive data since circular dichroism can only provide indirect evidence of correct 3-dimensional structure via information of secondary structure elements.

One preferred embodiment of the invention utilises multiple presentations of B-lymphocyte epitopes of APP or Aβ (*i.e.* formula I wherein at least one B-cell epitope is present in two positions). This effect can be achieved in various ways, e.g. by simply preparing fusion polypeptides comprising the structure (APP or Aβ derived polypeptide)$_m$, where m is an integer ≥ 2 and then introduce the modifications discussed herein in at

least one of the APP or Aβ sequences. It is preferred that the modifications introduced includes at least one duplication of a B-lymphocyte epitope and/or the introduction of a hapten. These embodiments including multiple presentations of selected epitopes are especially preferred in situations where merely minor parts of the APP or Aβ are useful as constituents in a vaccine agent.

As mentioned above, the introduction of a foreign T-cell epitope can be accomplished by introduction of at least one amino acid insertion, addition, deletion, or substitution. Of course, the normal situation will be the introduction of more than one change in the amino acid sequence (e.g. insertion of or substitution by a complete T-cell epitope) but the important goal to reach is that the analogue, when processed by an antigen presenting cell (APC), will give rise to such a foreign immunodominant T-cell epitope being presented in context of an MCH Class II molecule on the surface of the APC. Thus, if the amino acid sequence of the APP or Aβ in appropriate positions comprises a number of amino acid residues which can also be found in a foreign T_H epitope then the introduction of a foreign T_H epitope can be accomplished by providing the remaining amino acids of the foreign epitope by means of amino acid insertion, addition, deletion and substitution. In other words, it is not necessary to introduce a complete T_H epitope by insertion or substitution in order to fulfill the purpose of the present invention.

It is preferred that the number of amino acid insertions, deletions, substitutions or additions is at least 2, such as 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 25 insertions, substitutions, additions or deletions. It is furthermore preferred that the number of amino acid inser-

tions, substitutions, additions or deletions is not in excess of 150, such as at most 100, at most 90, at most 80, and at most 70. It is especially preferred that the number of substitutions, insertions, deletions, or additions does not exceed 60, and in particular the number should not exceed 50 or even 40. Most preferred is a number of not more than 30. With respect to amino acid additions, it should be noted that these, when the resulting construct is in the form of a fusion polypeptide, is often considerably higher than 150.

Preferred embodiments of the invention includes modification by introducing at least one foreign immunodominant T-cell epitope. It will be understood that the question of immune dominance of a T-cell epitope depends on the animal species in question. As used herein, the term "immunodominance" simply refers to epitopes which in the vaccinated individual/population gives rise to a significant immune response, but it is a well-known fact that a T-cell epitope which is immunodominant in one individual/population is not necessarily immunodominant in another individual of the same species, even though it may be capable of binding MHC-II molecules in the latter individual. Hence, for the purposes of the present invention, an immune dominant T-cell epitope is a T-cell epitope which will be effective in providing T-cell help when present in an antigen. Typically, immune dominant T-cell epitopes has as an inherent feature that they will substantially always be presented bound to an MHC Class II molecule, irrespective of the polypeptide wherein they appear.

Another important point is the issue of MHC restriction of T-cell epitopes. In general, naturally occurring T-cell epitopes are MHC restricted, *i.e.* a certain peptides constituting a T-cell epitope will only bind effectively to a subset of MHC

Class II molecules. This in turn has the effect that in most cases the use of one specific T-cell epitope will result in a vaccine component which is only effective in a fraction of the population, and depending on the size of that fraction, it can be necessary to include more T-cell epitopes in the same molecule, or alternatively prepare a multi-component vaccine wherein the components are variants of APP or Aβ which are distinguished from each other by the nature of the T-cell epitope introduced.

If the MHC restriction of the T-cells used is completely unknown (for instance in a situation where the vaccinated animal has a poorly defined MHC composition), the fraction of the population covered by a specific vaccine composition can be approximated by means of the following formula

$$f_{population} = 1 - \prod_{i=1}^{n} (1 - p_i) \qquad \text{(II)}$$

-where p_i is the frequency in the population of responders to the i^{th} foreign T-cell epitope present in the vaccine composition, and n is the total number of foreign T-cell epitopes in the vaccine composition. Thus, a vaccine composition containing 3 foreign T-cell epitopes having response frequencies in the population of 0.8, 0.7, and 0.6, respectively, would give

$$1 - 0.2 \times 0.3 \times 0.4 = 0.976$$

-*i.e.* 97.6 percent of the population will statistically mount an MHC-II mediated response to the vaccine.

The above formula does not apply in situations where a more or less precise MHC restriction pattern of the peptides used is known. If, for instance a certain peptide only binds the human MHC-II molecules encoded by HLA-DR alleles DR1, DR3, DR5, and

DR7, then the use of this peptide together with another peptide which binds the remaining MHC-II molecules encoded by HLA-DR alleles will accomplish 100% coverage in the population in question. Likewise, if the second peptide only binds DR3 and DR5, the addition of this peptide will not increase the coverage at all. If one bases the calculation of population response purely on MHC restriction of T-cell epitopes in the vaccine, the minimum fraction of the population covered by a specific vaccine composition can be determined by means of the following formula:

$$f_{population} = 1 - \prod_{j=1}^{3} (1 - \varphi_j)^2 \qquad \text{(III)}$$

-wherein φ_j is the sum of frequencies in the population of allelic haplotypes encoding MHC molecules which bind any one of the T-cell epitopes in the vaccine and which belong to the j^{th} of the 3 known HLA loci (DP, DR and DQ); in practice, it is first determined which MHC molecules will recognize each T-cell epitope in the vaccine and thereafter these are listed by type (DP, DR and DQ) - then, the individual frequencies of the different listed allelic haplotypes are summed for each type, thereby yielding φ_1, φ_2, and φ_3.

It may occur that the value p_i in formula II exceeds the corresponding theoretical value π_i:

$$\pi_i = 1 - \prod_{j=1}^{3} (1 - \nu_j)^2 \qquad \text{(IV)}$$

-wherein υ_j is the sum of frequencies in the population of allelic haplotype encoding MHC molecules which bind the i^{th} T-cell epitope in the vaccine and which belong to the j^{th} of the 3 known HLA loci (DP, DR and DQ). This means that in $1-\pi_i$ of the population is a frequency of responders of $f_{residual\_i} = (p_i -$

$\Pi_i)/(1-\Pi_i)$. Therefore, formula III can be adjusted so as to yield formula V:

$$f_{population} = 1 - \prod_{j=1}^{3}(1-\varphi_j)^2 + \left(1 - \prod_{i=1}^{n}(1-f_{residual\_i})\right) \qquad (V)$$

-where the term $1-f_{residual-i}$ is set to zero if negative. It should be noted that formula V requires that all epitopes have been haplotype mapped against identical sets of haplotypes.

Therefore, when selecting T-cell epitopes to be introduced in the analogue, it is important to include all knowledge of the epitopes which is available: 1) The frequency of responders in the population to each epitope, 2) MHC restriction data, and 3) frequency in the population of the relevant haplotypes.

There exist a number of naturally occurring "promiscuous" T-cell epitopes which are active in a large proportion of individuals of an animal species or an animal population and these are preferably introduced in the vaccine thereby reducing the need for a very large number of different analogues in the same vaccine.

The promiscuous epitope can according to the invention be a naturally occurring human T-cell epitope such as epitopes from tetanus toxoid (e.g. the P2 and P30 epitopes), diphtheria toxoid, Influenza virus hemagluttinin (HA), and *P. falciparum* CS antigen.

Over the years a number of other promiscuous T-cell epitopes have been identified. Especially peptides capable of binding a large proportion of HLA-DR molecules encoded by the different HLA-DR alleles have been identified and these are all possible T-cell epitopes to be introduced in the analogues used according to the present invention. Cf. also the epitopes discussed

in the following references which are hereby all incorporated by reference herein: WO 98/23635 (Frazer IH *et al.*, assigned to The University of Queensland); Southwood S *et. al*, 1998, J. Immunol. **160**: 3363-3373; Sinigaglia F *et al.*, 1988, Nature **336**: 778-780; Chicz RM *et al.*, 1993, J. Exp. Med **178**: 27-47; Hammer J *et al.*, 1993, Cell **74**: 197-203; and Falk K *et al.*, 1994, Immunogenetics **39**: 230-242. The latter reference also deals with HLA-DQ and -DP ligands. All epitopes listed in these 5 references are relevant as candidate natural epitopes to be used in the present invention, as are epitopes which share common motifs with these.

Alternatively, the epitope can be any artificial T-cell epitope which is capable of binding a large proportion of MHC Class II molecules. In this context the pan DR epitope peptides ("PADRE") described in WO 95/07707 and in the corresponding paper Alexander J *et al.*, 1994, Immunity **1**: 751-761 (both disclosures are incorporated by reference herein) are interesting candidates for epitopes to be used according to the present invention. It should be noted that the most effective PADRE peptides disclosed in these papers carry D-amino acids in the C- and N-termini in order to improve stability when administered. However, the present invention primarily aims at incorporating the relevant epitopes as part of the analogue which should then subsequently be broken down enzymatically inside the lysosomal compartment of APCs to allow subsequent presentation in the context of an MHC-II molecule and therefore it is not expedient to incorporate D-amino acids in the epitopes used in the present invention.

One especially preferred PADRE peptide is the one having the amino acid sequence AKFVAAWTLKAAA (SEQ ID NO: 17) or an immunologically effective subsequence thereof. This, and other

epitopes having the same lack of MHC restriction are preferred T-cell epitopes which should be present in the analogues used in the inventive method. Such super-promiscuous epitopes will allow for the most simple embodiments of the invention wherein only one single analogue is presented to the vaccinated animal's immune system.

As mentioned above, the modification of the APP or Aβ can also include the introduction of a first moiety which targets the modified amyloidogenic polypeptide to an APC or a B-lymphocyte. For instance, the first moiety can be a specific binding partner for a B-lymphocyte specific surface antigen or for an APC specific surface antigen. Many such specific surface antigens are known in the art. For instance, the moiety can be a carbohydrate for which there is a receptor on the B-lymphocyte or the APC (e.g. mannan or mannose). Alternatively, the second moiety can be a hapten. Also an antibody fragment which specifically recognizes a surface molecule on APCs or lymphocytes can be used as a first moiety (the surface molecule can e.g. be an FCγ receptor of macrophages and monocytes, such as FCγRI or, alternatively any other specific surface marker such as CD40 or CTLA-4). It should be noted that all these exemplary targeting molecules can be used as part of an adjuvant also, cf. below.

As an alternative or supplement to targeting the analogue to a certain cell type in order to achieve an enhanced immune response, it is possible to increase the level of responsiveness of the immune system by including the above-mentioned second moiety which stimulates the immune system. Typical examples of such second moieties are cytokines, and heat-shock proteins or molecular chaperones, as well as effective parts thereof.

Suitable cytokines to be used according to the invention are those which will normally also function as adjuvants in a vaccine composition, *i.e.* for instance interferon γ (IFN-γ), interleukin 1 (IL-1), interleukin 2 (IL-2), interleukin 4 (IL-4), interleukin 6 (IL-6), interleukin 12 (IL-12), interleukin 13 (IL-13), interleukin 15 (IL-15), and granulocyte-macrophage colony stimulating factor (GM-CSF); alternatively, the functional part of the cytokine molecule may suffice as the second moiety. With respect to the use of such cytokines as adjuvant substances, cf. the discussion below.

According to the invention, suitable heat-shock proteins or molecular chaperones used as the second moiety can be HSP70, HSP90, HSC70, GRP94 (also known as gp96, cf. Wearsch PA *et al.* 1998, Biochemistry **37**: 5709-19), and CRT (calreticulin).

Alternatively, the second moiety can be a toxin, such as listeriolycin (LLO), lipid A and heat-labile enterotoxin. Also, a number of mycobacterial derivatives such as MDP (muramyl dipeptide), CFA (complete Freund's adjuvant) and the trehalose diesters TDM and TDE are interesting possibilities.

Also the possibility of introducing a third moiety which enhances the presentation of the analogue to the immune system is an important embodiment of the invention. The art has shown several examples of this principle. For instance, it is known that the palmitoyl lipidation anchor in the *Borrelia burgdorferi* protein OspA can be utilised so as to provide self-adjuvating polypeptides (cf. e.g. WO 96/40718) - it seems that the lipidated proteins form up micelle-like structures with a core consisting of the lipidation anchor parts of the polypeptides and the remaining parts of the molecule protruding therefrom, resulting in multiple presentations of the antigenic determi-

nants. Hence, the use of this and related approaches using different lipidation anchors (e.g. a myristyl group, a myristyl group, a farnesyl group, a geranyl-geranyl group, a GPI-anchor, and an N-acyl diglyceride group) are preferred embodiments of the invention, especially since the provision of such a lipidation anchor in a recombinantly produced protein is fairly straightforward and merely requires use of e.g. a naturally occurring signal sequence as a fusion partner for the analogue. Another possibility is use of the C3d fragment of complement factor C3 or C3 itself (cf. Dempsey *et al.*, 1996, Science **271**, 348-350 and Lou & Kohler, 1998, Nature Biotechnology **16**, 458-462).

An alternative embodiment of the invention which also results in the preferred presentation of multiple (e.g. at least 2) copies of the important epitopic regions of APP or Aβ to the immune system is the covalent coupling of the analogue to certain molecules, *i.e.* variants d and e mentioned above. For instance, polymers can be used, e.g. carbohydrates such as dextran, cf. e.g. Lees A et al., 1994, Vaccine 12: 1160-1166; Lees A et al., 1990, J Immunol. 145: 3594-3600, but also mannose and mannan are useful alternatives. Integral membrane proteins from e.g. E. coli and other bacteria are also useful conjugation partners. The traditional carrier molecules such as keyhole limpet hemocyanin (KLH), tetanus toxoid, diphtheria toxoid, and bovine serum albumin (BSA) are also preferred and useful conjugation partners.

Preferred embodiments of covalent coupling of the APP or Aβ derived material to polyhydroxypolymers such as carbohydrates involve the use of at least one APP or Aβ derived peptide and at least one foreign T-helper epitope which are coupled separately to the polyhydroxypolymer (i.e. the foreign T-helper

epitope and the APP or Aβ derived amino acid sequence are not fused to each other but rather bound to the polyhydroxypolymer which then serves as a carrier backbone). Again, such an embodiment is most preferred when the suitable B-cell epitope carrying regions of the APP or Aβ derived peptides are constituted by short peptide stretches - this is because this approach is one very convenient way to achieve multiple presentations of selected epitopes in the resulting immunogenic agent. It is, however, also possible to simply coupled analogues already described herein to the polyhydroxypolymer backbone, *i.e.* that the APP or Aβ derived material is not attached to the backbone separately from the foreign T_H epitopes.

It is especially preferred that the coupling of the foreign T-helper epitope and the APP or Aβ derived (poly)peptide is by means of an amide bond which can be cleaved by a peptidase. This strategy has the effect that APCs will be able to take up the conjugate and at the same time be able to process the conjugate and subsequently present the foreign T-cell epitope in an MHC Class II context.

One way of achieving coupling of peptides (both the APP or Aβ derived peptide of interest as well as the foreign epitope) is to activate a suitable polyhydroxypolymer with tresyl (trifluoroethylsulphonyl) groups or other suitable activation groups such as maleimido, p-Nitrophenyl cloroformate (for activation of OH groups and formation of a peptide bond between peptide and polyhydroxypolymer), and tosyl (p-toluenesulfonyl). It is e.g. possible to prepare activated polysaccharides as described in WO 00/05316 and US 5,874,469 (both incorporated by reference herein) and couple these to APP or Aβ derived peptides or polyamino acids as well as to T-cell epi-

topes prepared by means of conventional solid or liquid phase peptide synthesis techniques. The resulting product consists of a polyhydroxypolymer backbone (e.g. a dextran backbone) that has, attached thereto by their N-termini or by other available nitrogen moieties, polyamino acids derived from APP or Aβ and from foreign T-cell epitopes. If desired, it is possible to synthesise the APP or Aβ peptides so as to protect all available amino groups but the one at the N-terminus, subsequently couple the resulting protected peptides to the tresylated dextran moiety, and finally de-protecting the resulting conjugate. A specific example of this approach is described in the examples below.

Instead of using the water-soluble polysaccharide molecules as taught in WO 00/05316 and US 5,874,469, it is equally possible to utilise cross-linked polysaccharide molecules, thereby obtaining a particulate conjugate between polypeptides and polysaccharide - this is believed to lead to an improved presentation to the immune system of the polypeptides, since two goals are reached, namely to obtain a local deposit effect when injecting the conjugate and to obtain particles which are attractive targets for APCs. The approach of using such particulate systems is also detailed in the examples.

Considerations underlying chosen areas of introducing modifications in APP or Aβ are a) preservation of known and predicted B-cell epitopes, b) preservation of tertiary structure, c) avoidance of B-cell epitopes present on "producer cells" etc. At any rate, as discussed above, it is fairly easy to screen a set of analogues which have all been subjected to introduction of a T-cell epitope in different locations.

Since the most preferred embodiments of the present invention involve down-regulation of human Aβ, it is consequently preferred that the APP or Aβpolypeptide discussed above is a human Aβ polypeptide. In this embodiment, it is especially preferred that the APP or Aβ polypeptide has been modified by substituting at least one amino acid sequence in SEQ ID NO: 2 with at least one amino acid sequence of equal or different length and containing a foreign T_H epitope. Preferred examples of modified amyloidogenic APP and Aβ are shown schematically in Fig. 1 using the P2 and P30 epitopes as examples. The rationale behind such constructs is discussed in detail in the examples.

More specifically, a T_H containing (or completing) amino acid sequence which is introduced into SEQ ID NO: 2 may be introduced at any amino acid in SEQ ID NO: 2. That is, the introduction is possible after any of amino acids 1-770, but preferably after any of amino acids 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, and 714 in SEQ ID NO: 2. This may be combined with deletion of any or all of amino acids 1-671, or any of all of amino acids 715-770. Furthermore, when utilising the technique of substitution, any one of amino acids 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, and 714 in SEQ ID NO: 2 may be deleted in combination with the introduction.

Another embodiment of the present invention is the presentation of the analogues which do not include any subsequence of

of SEQ ID NO: 2 that binds productively to MHC class II molecules initiating a T-cell response.

The rationale behind such a strategy for design of the immunogen that engages the immune system to induce e.g. an anti-Aβ immune response is the following: It has been noted that when immunizing with abundant autologous proteins such as Aβ formulated in an adjuvant which is sufficiently strong to break the body's tolerance towards the autologous protein, there is a danger that in some vaccinated individuals the immune response induced cannot be discontinued simply by discontinueing the immunisation. This is because the induced immune response in such individuals is most likely driven by a native T_H epitope of the autologous protein, and this has the adverse effect that the vaccinated individual's own protein will be able to function as an immunizing agent in its own right: An autoimmune condition has thus been established.

The preferred methods including use of foreign T_H epitopes have to the best of the inventors' knowledge never been observed to produce this effect, because the anti-self immune response is driven by a *foreign* T_H epitope, and it has been repeatedly demonstrated by the inventors that the induced immune response invoked by the preferred technology indeed declines after discontinuation of immunizations. However, in theory it could happen in a few individuals that the immune response would also be driven by an autologous T_H epitope of the relevant self-protein one immunises against) - this is especially relevant when considering self-proteins that are relatively abundant, such as Aβ, whereas other therapeutically relevant self-proteins are only present locally or in so low amounts in the body, that a "self-immunization effect" is not a possibility. One very simple way of avoiding this is hence to altogether

avoid inclusion in the immunogen of peptide sequences that *could* serve as T_H epitopes (and since peptides shorter than about 9 amino acids cannot serve as T_H epitopes, the use of shorter fragments is one simple and feasible approach). Therefore, this embodiment of the invention also serves to ensure that the immunogen does not indlude peptide sequences of the target APP or Aβ that could serve as "self-stimulating T_H epitopes" including sequences that merely contain conservative substitutions in a sequence of the target protein that might otherwise function as a T_H epitope.

Preferred embodiments of the immune system presentation of the analogues of the APP or Aβ involve the use of a chimeric peptide comprising at least one APP or Aβ derived peptide, which does not bind productively to MHC class II molecules, and at least one foreign T-helper epitope. Moreover, it is preferred that the APP or Aβ derived peptide harbours a B-cell epitope. It is especially advantageous if the immunogenic analogue is one, wherein the amino acid sequences comprising one or more B-cell epitopes are represented either as a continuous sequence or as a sequence including inserts, wherein the inserts comprise foreign T-helper epitopes.

Again, such an embodiment is most preferred when the suitable B-cell epitope carrying regions of the APP or Aβ are constituted by short peptide stretches that in no way would be able to bind productively to an MHC Class II molecule. The selected B-cell epitope or -epitopes of the amyloidogenic polypeptide should therefore comprise at most 9 consecutive amino acids of SEQ ID NO: 2. Shorter peptides are preferred, such as those having at most 8, 7, 6, 5, 4, or 3 consecutive amino acids from the amyloidogenic polypeptide's amino acid sequence.

It is preferred that the analogue comprises at least one subsequence of SEQ ID NO: 2 so that each such at least one subsequence independently consists of amino acid stretches from the APP or Aβ selected from the group consisting of 9 consecutive amino acids, 8 consecutive amino acids, 7 consecutive amino acids, 6 consecutive amino acids, 5 consecutive amino acids, 4 consecutive amino acids, and 3 consecutive amino acids.

It is especially preferred that the consecutive amino acids begins at an amino acid residue selected from the group consisting of residue 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, and 714 of SEQ ID NO: 2.

Protein/peptide vaccination; formulation and administration of the analogues

When effecting presentation of the analogue to an animal's immune system by means of administration thereof to the animal, the formulation of the polypeptide follows the principles generally acknowledged in the art.

Preparation of vaccines which contain peptide sequences as active ingredients is generally well understood in the art, as exemplified by U.S. Patents 4,608,251; 4,601,903; 4,599,231; 4,599,230; 4,596,792; and 4,578,770, all incorporated herein by reference. Typically, such vaccines are prepared as injectables either as liquid solutions or suspensions; solid forms suitable for solution in, or suspension in, liquid prior to injection may also be prepared. The preparation may also be emulsified. The active immunogenic ingredient is often mixed with excipients which are pharmaceutically acceptable and com-

patible with the active ingredient. Suitable excipients are, for example, water, saline, dextrose, glycerol, ethanol, or the like, and combinations thereof. In addition, if desired, the vaccine may contain minor amounts of auxiliary substances such as wetting or emulsifying agents, pH buffering agents, or adjuvants which enhance the effectiveness of the vaccines; cf. the detailed discussion of adjuvants below.

The vaccines are conventionally administered parenterally, by injection, for example, either subcutaneously, intracutaneously, or intramuscularly. Additional formulations which are suitable for other modes of administration include suppositories and, in some cases, oral, buccal, sublinqual, intraperitoneal, intravaginal, anal, epidural, spinal, and intracranial formulations. For suppositories, traditional binders and carriers may include, for example, polyalkalene glycols or triglycerides; such suppositories may be formed from mixtures containing the active ingredient in the range of 0.5% to 10%, preferably 1-2%. Oral formulations include such normally employed excipients as, for example, pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, magnesium carbonate, and the like. These compositions take the form of solutions, suspensions, tablets, pills, capsules, sustained release formulations or powders and contain 10-95% of active ingredient, preferably 25-70%. For oral formulations, cholera toxin is an interesting formulation partner (and also a possible conjugation partner).

The polypeptides may be formulated into the vaccine as neutral or salt forms. Pharmaceutically acceptable salts include acid addition salts (formed with the free amino groups of the peptide) and which are formed with inorganic acids such as, for example, hydrochloric or phosphoric acids, or such organic a-

cids as acetic, oxalic, tartaric, mandelic, and the like. Salts formed with the free carboxyl groups may also be derived from inorganic bases such as, for example, sodium, potassium, ammonium, calcium, or ferric hydroxides, and such organic bases as isopropylamine, trimethylamine, 2-ethylamino ethanol, histidine, procaine, and the like.

The vaccines are administered in a manner compatible with the dosage formulation, and in such amount as will be therapeutically effective and immunogenic. The quantity to be administered depends on the subject to be treated, including, e.g., the capacity of the individual's immune system to mount an immune response, and the degree of protection desired. Suitable dosage ranges are of the order of several hundred micrograms active ingredient per vaccination with a preferred range from about 0.1 µg to 2,000 µg (even though higher amounts in the 1-10 mg range are contemplated), such as in the range from about 0.5 µg to 1,000 µg, preferably in the range from 1 µg to 500 µg and especially in the range from about 10 µg to 100 µg. Suitable regimens for initial administration and booster shots are also variable but are typified by an initial administration followed by subsequent inoculations or other administrations.

The manner of application may be varied widely. Any of the conventional methods for administration of a vaccine are applicable. These include oral application on a solid physiologically acceptable base or in a physiologically acceptable dispersion, parenterally, by injection or the like. The dosage of the vaccine will depend on the route of administration and will vary according to the age of the person to be vaccinated and the formulation of the antigen.

Some of the polypeptides of the vaccine are sufficiently immunogenic in a vaccine, but for some of the others the immune response will be enhanced if the vaccine further comprises an adjuvant substance.

Various methods of achieving adjuvant effect for the vaccine are known. General principles and methods are detailed in "The Theory and Practical Application of Adjuvants", 1995, Duncan E.S. Stewart-Tull (ed.), John Wiley & Sons Ltd, ISBN 0-471-95170-6, and also in "Vaccines: New Generationn Immunological Adjuvants", 1995, Gregoriadis G *et al.* (eds.), Plenum Press, New York, ISBN 0-306-45283-9, both of which are hereby incorporated by reference herein.

It is especially preferred to use an adjuvant which can be demonstrated to facilitate breaking of the autotolerance to autoantigens; in fact, this is essential in cases where unmodified amyloidogenic polypeptide is used as the active ingredient in the autovaccine. Non-limiting examples of suitable adjuvants are selected from the group consisting of an immune targeting adjuvant; an immune modulating adjuvant such as a toxin, a cytokine, and a mycobacterial derivative; an oil formulation; a polymer; a micelle forming adjuvant; a saponin; an immunostimulating complex matrix (ISCOM matrix); a particle; DDA; aluminium adjuvants; DNA adjuvants; γ-inulin; and an encapsulating adjuvant. In general it should be noted that the disclosures above which relate to compounds and agents useful as first, second and third moieties in the analogues also refer *mutatis mutandis* to their use in the adjuvant of a vaccine of the invention.

The application of adjuvants include use of agents such as aluminum hydroxide or phosphate (alum), commonly used as 0.05

to 0.1 percent solution in buffered saline, admixture with synthetic polymers of sugars (e.g. Carbopol®) used as 0.25 percent solution, aggregation of the protein in the vaccine by heat treatment with temperatures ranging between 70° to 101°C for 30 second to 2 minute periods respectively and also aggregation by means of cross-linking agents are possible. Aggregation by reactivation with pepsin treated antibodies (Fab fragments) to albumin, mixture with bacterial cells such as *C. parvum* or endotoxins or lipopolysaccharide components of gram-negative bacteria, emulsion in physiologically acceptable oil vehicles such as mannide mono-oleate (Aracel A) or emulsion with 20 percent solution of a perfluorocarbon (Fluosol-DA) used as a block substitute may also be employed. Admixture with oils such as squalene and IFA is also preferred.

According to the invention DDA (dimethyldioctadecylammonium bromide) is an interesting candidate for an adjuvant as is DNA and γ-inulin, but also Freund's complete and incomplete adjuvants as well as *quillaja* saponins such as QuilA and QS21 are interesting as is RIBI. Further possibilities are monophosphoryl lipid A (MPL), the above mentioned C3 and C3d, and muramyl dipeptide (MDP).

Liposome formulations are also known to confer adjuvant effects, and therefore liposome adjuvants are preferred according to the invention.

Also immunostimulating complex matrix type (ISCOM® matrix) adjuvants are preferred choices according to the invention, especially since it has been shown that this type of adjuvants are capable of up-regulating MHC Class II expression by APCs. An ISCOM® matrix consists of (optionally fractionated) saponins (triterpenoids) from *Quillaja saponaria*, cholesterol, and

phospholipid. When admixed with the immunogenic protein, the resulting particulate formulation is what is known as an ISCOM particle where the saponin constitutes 60-70% w/w, the cholesterol and phospholipid 10-15% w/w, and the protein 10-15% w/w. Details relating to composition and use of immunostimulating complexes can e.g. be found in the above-mentioned text-books dealing with adjuvants, but also Morein B *et al.*, 1995, Clin. Immunother. **3**: 461-475 as well as Barr IG and Mitchell GF, 1996, Immunol. and Cell Biol. **74**: 8-25 (both incorporated by reference herein) provide useful instructions for the preparation of complete immunostimulating complexes.

Another highly interesting (and thus, preferred) possibility of achieving adjuvant effect is to employ the technique described in Gosselin *et al.*, 1992 (which is hereby incorporated by reference herein). In brief, the presentation of a relevant antigen such as an antigen of the present invention can be enhanced by conjugating the antigen to antibodies (or antigen binding antibody fragments) against the Fcγ receptors on monocytes/macrophages. Especially conjugates between antigen and anti-FcγRI have been demonstrated to enhance immunogenicity for the purposes of vaccination.

Other possibilities involve the use of the targeting and immune modulating substances (*i.a.* cytokines) mentioned above as candidates for the first and second moieties in the modified versions of amyloidogenic polypeptides. In this connection, also synthetic inducers of cytokines like poly I:C are possibilities.

Suitable mycobacterial derivatives are selected from the group consisting of muramyl dipeptide, complete Freund's adjuvant, RIBI, and a diester of trehalose such as TDM and TDE.

Suitable immune targeting adjuvants are selected from the group consisting of CD40 ligand and CD40 antibodies or specifically binding fragments thereof (cf. the discussion above), mannose, a Fab fragment, and CTLA-4.

Suitable polymer adjuvants are selected from the group consisting of a carbohydrate such as dextran, PEG, starch, mannan, and mannose; a plastic polymer such as; and latex such as latex beads.

Yet another interesting way of modulating an immune response is to include the immunogen (optionally together with adjuvants and pharmaceutically acceptable carriers and vehicles) in a "virtual lymph node" (VLN) (a proprietary medical device developed by ImmunoTherapy, Inc., 360 Lexington Avenue, New York, NY 10017-6501). The VLN (a thin tubular device) mimics the structrue and function of a lymph node. Insertion of a VLN under the skin creates a site of sterile inflammation with an upsurge of cytokines and chemokines. T- and B-cells as well as APCs rapidly respond to the danger signals, home to the inflamed site and accumulate inside the porous matrix of the VLN. It has been shown that the necessary antigen dose required to mount an immune response to an antigen is reduced when using the VLN and that immune protection conferred by vaccination using a VLN surpassed conventional immunization using Ribi as an adjuvant. The technology is *i.a.* described briefly in Gelber C *et al.*, 1998, "Elicitation of Robust Cellular and Humoral Immune Responses to Small Amounts of Immunogens Using a Novel Medical Device Designated the Virtual Lymph Node", in: "From the Laboratory to the Clinic, Book of Abstracts, October 12th - 15th 1998, Seascape Resort, Aptos, California".

Microparticle formulation of vaccines has been shown in many cases to increase the immunogenicity of protein antigens and is therefore another preferred embodiment of the invention. Microparticles are made either as co-formulations of antigen with a polymer, a lipid, a carbohydrate or other molecules suitable for making the particles, or the microparticles can be homogeneous particles consisting of only the antigen itself.

Examples of polymer based microparticles are PLGA and PVP based particles (Gupta, R.K. et. al. 1998) where the polymer and the antigen are condensed into a solid particle. Lipid based particles can be made as micelles of the lipid (so-called liposomes) entrapping the antigen within the micelle (Pietrobon, P.J. 1995). Carbohydrate based particles are typically made of a suitable degradable carbohydrate such as starch or chitosan. The carbohydrate and the antigen are mixed and condensed into particles in a process similar to the one used for polymer particles (Kas, H.S. et. al. 1997).

Particles consisting only of the antigen can be made by various spraying and freeze-drying techniques. Especially suited for the purporses of the present invention is the super critical fluid technology that is used to make very uniform particles of controlled size (York, P. 1999 & Shekunov, B. et. al. 1999).

It is expected that the vaccine should be administered 1-6 times per year, such as 1, 2, 3, 4, 5, or 6 times a year to an individual in need thereof. It has previously been shown that the memory immunity induced by the use of the preferred autovaccines according to the invention is not permanent, and therefore the immune system needs to be periodically chal-

lenged with the amyloidogenic polypeptide or modified amyloidogenic polypeptides.

Due to genetic variation, different individuals may react with immune responses of varying strength to the same polypeptide. Therefore, the vaccine according to the invention may comprise several different polypeptides in order to increase the immune response, cf. also the discussion above concerning the choice of foreign T-cell epitope introductions. The vaccine may comprise two or more polypeptides, where all of the polypeptides are as defined above.

The vaccine may consequently comprise 3-20 different modified or unmodified polypeptides, such as 3-10 different polypeptides.

Nucleic acid vaccination

As an alternative to classic administration of a peptide-based vaccine, the technology of nucleic acid vaccination (also known as "nucleic acid immunisation", "genetic immunisation", and "gene immunisation") offers a number of attractive features.

First, in contrast to the traditional vaccine approach, nucleic acid vaccination does not require resource consuming large-scale production of the immunogenic agent (e.g. in the form of industrial scale fermentation of microorganisms producing modified amyloidogenic polypeptides). Furthermore, there is no need to device purification and refolding schemes for the immunogen. And finally, since nucleic acid vaccination relies on the biochemical apparatus of the vaccinated individual in order to produce the expression product of the nucleic acid introduced, the optimum post-translational processing of

the expression product is expected to occur; this is especially important in the case of autovaccination, since, as mentioned above, a significant fraction of the original B-cell epitopes should be preserved in the modified molecule, and since B-cell epitopes in principle can be constituted by parts of any (bio)molecule (e.g. carbohydrate, lipid, protein etc.). Therefore, native glycosylation and lipidation patterns of the immunogen may very well be of importance for the overall immunogenicity and this is best ensured by having the host producing the immunogen.

Hence, a preferred embodiment of the invention's variants a-c comprises effecting presentation of the analogue to the immune system by introducing nucleic acid(s) encoding the analogue into the animal's cells and thereby obtaining *in vivo* expression by the cells of the nucleic acid(s) introduced.

In this embodiment, the introduced nucleic acid is preferably DNA which can be in the form of naked DNA, DNA formulated with charged or uncharged lipids, DNA formulated in liposomes, DNA included in a viral vector, DNA formulated with a transfection-facilitating protein or polypeptide, DNA formulated with a targeting protein or polypeptide, DNA formulated with Calcium precipitating agents, DNA coupled to an inert carrier molecule, DNA encapsulated in a polymer, e.g. in PLGA (cf. the microencapsulation technology described in WO 98/31398) or in chitin or chitosan, and DNA formulated with an adjuvant. In this context it is noted that practically all considerations pertaining to the use of adjuvants in traditional vaccine formulation apply for the formulation of DNA vaccines. Hence, all disclosures herein which relate to use of adjuvants in the context of polypeptide based vaccines apply *mutatis mutandis* to their use in nucleic acid vaccination technology.

As for routes of administration and administration schemes of polypeptide based vaccines which have been detailed above, these are also applicable for the nucleic acid vaccines of the invention and all discussions above pertaining to routes of administration and administration schemes for polypeptides apply *mutatis mutandis* to nucleic acids. To this should be added that nucleic acid vaccines can suitably be administered intraveneously and intraarterially. Furthermore, it is well-known in the art that nucleic acid vaccines can be administered by use of a so-called gene gun, and hence also this and equivalent modes of administration are regarded as part of the present invention. Finally, also the use of a VLN in the administration of nucleic acids has been reported to yield good results, and therefore this particular mode of administration is particularly preferred.

Furthermore, the nucleic acid(s) used as an immunization agent can contain regions encoding the 1st, 2nd and/or 3rd moieties, e.g. in the form of the immunomodulating substances described above such as the cytokines discussed as useful adjuvants. A preferred version of this embodiment encompasses having the coding region for the analogue and the coding region for the immunomodulator in different reading frames or at least under the control of different promoters. Thereby it is avoided that the analogue or epitope is produced as a fusion partner to the immunomodulator. Alternatively, two distinct nucleotide fragments can be used, but this is less preferred because of the advantage of ensured co-expression when having both coding regions included in the same molecule.

Accordingly, the invention also relates to a composition for inducing production of antibodies against APP or Aβ, the composition comprising

- a nucleic acid fragment or a vector of the invention (cf. the discussion of vectors below), and

- a pharmaceutically and immunologically acceptable vehicle and/or carrier and/or adjuvant as discussed above.

Under normal circumstances, the variant-encoding nucleic acid is introduced in the form of a vector wherein expression is under control of a viral promoter. For more detailed discussions of vectors according to the invention, cf. the discussion below. Also, detailed disclosures relating to the formulation and use of nucleic acid vaccines are available, cf. Donnelly JJ *et al*, 1997, Annu. Rev. Immunol. **15**: 617-648 and Donnelly JJ *et al*., 1997, Life Sciences **60**: 163-172. Both of these references are incorporated by reference herein.

Live vaccines

A third alternative for effecting presentation of the analogues as these are defined in variants a-c to the immune system is the use of live vaccine technology. In live vaccination, presentation to the immune system is effected by administering, to the animal, a non-pathogenic microorganism which has been transformed with a nucleic acid fragment encoding an analogue or with a vector incorporating such a nucleic acid fragment. The non-pathogenic microorganism can be any suitable attenuated bacterial strain (attenuated by means of passaging or by means of removal of pathogenic expression products by recombinant DNA technology), e.g. *Mycobacterium bovis* BCG., non-pathogenic *Streptococcus* spp., *E. coli*, *Salmonella* spp., *Vibrio cholerae*, *Shigella*, etc. Reviews dealing with preparation of state-of-the-art live vaccines can e.g. be found in Saliou P, 1995, Rev. Prat. **45**: 1492-1496 and Walker PD, 1992, Vaccine **10**: 977-990, both incorporated by reference herein.

For details about the nucleic acid fragments and vectors used in such live vaccines, cf. the discussion below.

As an alternative to bacterial live vaccines, the nucleic acid fragment of the invention discussed below can be incorporated in a non-virulent viral vaccine vector such as a vaccinia strain or any other suitable poxvirus.

Normally, the non-pathogenic microorganism or virus is administered only once to the animal, but in certain cases it may be necessary to administer the microorganism more than once in a lifetime in order to maintain protective immunity. It is even contemplated that immunization schemes as those detailed above for polypeptide vaccination will be useful when using live or virus vaccines.

Alternatively, live or virus vaccination is combined with previous or subsequent polypeptide and/or nucleic acid vaccination. For instance, it is possible to effect primary immunization with a live or virus vaccine followed by subsequent booster immunizations using the polypeptide or nucleic acid approach.

The microorganism or virus can be transformed with nucleic acid(s) containing regions encoding the 1st, 2nd and/or 3rd moieties, e.g. in the form of the immunomodulating substances described above such as the cytokines discussed as useful adjuvants. A preferred version of this embodiment encompasses having the coding region for the analogue and the coding region for the immunomodulator in different reading frames or at least under the control of different promoters. Thereby it is avoided that the analogue or epitopes are produced as fusion partners to the immunomodulator. Alternatively, two distinct nucleotide fragments can be used as transforming agents. Of

course, having the 1st and/or 2nd and/or 3rd moieties in the same reading frame can provide as an expression product, an analogue of the invention, and such an embodiment is especially preferred according to the present invention.

Use of the method of the invention in disease treatment

As will be appreciated from the discussions above, the provision of the method of the invention allows for control of diseases characterized by amyloid deposits. In this context, AD is the key target for the inventive method but also other diseases characterized by Aβ containing amyloid deposits are feasible targets. Hence, an important embodiment of the method of the invention for down-regulating amyloid activity comprises treating and/or preventing and/or ameliorating AD or other diseases characterized by amyloid deposition, the method comprising down-regulating APP or Aβ according to the method of the invention to such an extent that the amount of amyloid is significantly decreased.

It is especially preferred that the reduction in amyloid results in an inversion of the balance between amyloid formation and amyloid degradation/removal, *i.e.* that the rate of amyloid degradation/removal is brought to exceed the rate of amyloid formation. By carefully controlling the number and immunological impact of immunizations of the individual in need thereof it will be possible to obtain a balance over time which results in a net reduction of amyloid deposits without having excessive adverse effects.

Alternatively, if in an individual the method of the invention cannot remove or reduce existing amyloid deposits, the method of the invention can be used to obtain a clinically signifi-

cant reduction in the formation of new amyloid, thereby significantly prolonging the time where the disease condition is non-debilitating. It should be possible to monitor the rate of amyloid depositing by either measuring the serum concentration of amyloid (which is believed to be in equilibrium with the deposited material), or by using positron-emission tomography (PET) scanning, cf. Small GW, *et al.*, 1996, Ann N Y Acad Sci 802: 70-78.

Other diseases and conditions where the present means and methods may be used in treatment or amelioration in an analogous way have been mentioned above in the "Background of the invention" or are listed below in the section headed "other amyloidic diseases and proteins associated therewith".

Peptides, polypeptides, and compositions of the invention

As will be apparent from the above, the present invention is based on the concept of immunising individuals against the APP or Aβ antigen in order to obtain a reduced amount of pathology-related amyloid deposits. The preferred way of obtaining such an immunization is to use the analogues described herein, thereby providing molecules which have not previously been disclosed in the art.

It is believed that the analogues discussed herein are inventive in their own right, and therefore an important part of the invention pertains to an analogue as described above. Hence, any disclosure presented herein pertaining to modified APP or Aβ are relevant for the purpose of describing the amyloidogenic analogues of the invention, and any such disclosures apply *mutatis mutandis* to the description of these analogues.

It should be noted that preferred modified APP or Aβ molecules comprise modifications which results in a polypeptide having a sequence identity of at least 70% with APP or Aβ or with a subsequence thereof of at least 10 amino acids in length. Higher sequence identities are preferred, e.g. at least 75% or even at least 80, 85, 90, or 95%. The sequence identity for proteins and nucleic acids can be calculated as $(N_{ref} - N_{dif})\cdot 100/N_{ref}$, wherein N_{dif} is the total number of non-identical residues in the two sequences when aligned and wherein N_{ref} is the number of residues in one of the sequences. Hence, the DNA sequence AGTCAGTC will have a sequence identity of 75% with the sequence AATCAATC (N_{dif}=2 and N_{ref}=8).

The invention also pertains to compositions useful in exercising the method of the invention. Hence, the invention also relates to an immunogenic composition comprising an immunogenically effective amount of an analouge as described above, said composition further comprising a pharmaceutically and immunologically acceptable diluent and/or vehicle and/or carrier and/or excipient and optionally an adjuvant. In other words, this part of the invention concerns formulations of analogues, essentially as described above. The choice of adjuvants, carriers, and vehicles is accordingly in line with what has been discussed above when referring to formulation of modified and unmodified amyloidogenic polypeptide for use in the inventive method for the down-regulation of APP or Aβ.

The polypeptides are prepared according to methods well-known in the art. Longer polypeptides are normally prepared by means of recombinant gene technology including introduction of a nucleic acid sequence encoding the analogue into a suitable vector, transformation of a suitable host cell with the vector, expression by the host cell of the nucleic acid sequence, re-

covery of the expression product from the host cells or their culture supernatant, and subseqeunt purification and optional further modification, e.g. refolding or derivatization.

Shorter peptides are preferably prepared by means of the well-known techniques of solid- or liquid-phase peptide synthesis. However, recent advances in this technology has rendered possible the production of full-length polypeptides and proteins by these means, and therefore it is also within the scope of the present invention to prepare the long constructs by synthetic means.

Nucleic acid fragments and vectors of the invention

It will be appreciated from the above disclosure that polyamino acid analogues can be prepared by means of recombinant gene technology but also by means of chemical synthesis or semisynthesis; the latter two options are especially relevant when the modification consists in coupling to protein carriers (such as KLH, diphtheria toxoid, tetanus toxoid, and BSA) and non-proteinaceous molecules such as carbohydrate polymers and of course also when the modification comprises addition of side chains or side groups to an APP or Aβ derived peptide chain.

For the purpose of recombinant gene technology, and of course also for the purpose of nucleic acid immunization, nucleic acid fragments encoding analogues are important chemical products. Hence, an important part of the invention pertains to a nucleic acid fragment which encodes an analogue of the invention, *i.e.* an APP or Aβ derived polypeptide which either comprises the natural sequence to which has been added or inserted a fusion partner or, preferably an APP or Aβ derived

polypeptide wherein has been introduced a foreign T-cell epitope by means of insertion and/or addition, preferably by means of substitution and/or deletion. The nucleic acid fragments of the invention are either DNA or RNA fragments.

The nucleic acid fragments of the invention will normally be inserted in suitable vectors to form cloning or expression vectors carrying the nucleic acid fragments of the invention; such novel vectors are also part of the invention. Details concerning the construction of these vectors of the invention will be discussed in context of transformed cells and microorganisms below. The vectors can, depending on purpose and type of application, be in the form of plasmids, phages, cosmids, mini-chromosomes, or virus, but also naked DNA which is only expressed transiently in certain cells is an important vector. Preferred cloning and expression vectors of the invention are capable of autonomous replication, thereby enabling high copy-numbers for the purposes of high-level expression or high-level replication for subsequent cloning.

The general outline of a vector of the invention comprises the following features in the 5'→3' direction and in operable linkage: a promoter for driving expression of the nucleic acid fragment of the invention, optionally a nucleic acid sequence encoding a leader peptide enabling secretion (to the extracellular phase or, where applicable, into the periplasma) of or integration into the membrane of the polypeptide fragment, the nucleic acid fragment of the invention, and optionally a nucleic acid sequence encoding a terminator. When operating with expression vectors in producer strains or cell-lines it is for the purposes of genetic stability of the transformed cell preferred that the vector when introduced into a host cell is integrated in the host cell genome. In contrast, when working

with vectors to be used for effecting *in vivo* expression in an animal (*i.e.* when using the vector in DNA vaccination) it is for security reasons preferred that the vector is incapable of being integrated in the host cell genome; typically, naked DNA or non-integrating viral vectors are used, the choices of which are well-known to the person skilled in the art

The vectors of the invention are used to transform host cells to produce the analogue of the invention. Such transformed cells, which are also part of the invention, can be cultured cells or cell lines used for propagation of the nucleic acid fragments and vectors of the invention, or used for recombinant production of the analogues of the invention. Alternatively, the transformed cells can be suitable live vaccine strains wherein the nucleic acid fragment (one single or multiple copies) have been inserted so as to effect secretion or integration into the bacterial membrane or cell-wall of the analogue.

Preferred transformed cells of the invention are microorganisms such as bacteria (such as the species *Escherichia* [e.g. *E.coli*], *Bacillus* [e.g. *Bacillus subtilis*], *Salmonella*, or *Mycobacterium* [preferably non-pathogenic, e.g. *M. bovis* BCG]), yeasts (such as *Saccharomyces cerevisiae*), and protozoans. Alternatively, the transformed cells are derived from a multicellular organism such as a fungus, an insect cell, a plant cell, or a mammalian cell. Most preferred are cells derived from a human being, cf. the discussion of cell lines and vectors below. Recent results have shown great promise in the use of a commercially available *Drosophila melanogaster* cell line (the Schneider 2 (S_2) cell line and vector system available from Invitrogen) for the recombinant production of polypep-

tides in applicants' lab, and therefore this expression system is particularly preferred.

For the purposes of cloning and/or optimized expression it is preferred that the transformed cell is capable of replicating the nucleic acid fragment of the invention. Cells expressing the nucleic fragment are preferred useful embodiments of the invention; they can be used for small-scale or large-scale preparation of the analogue of the invention or, in the case of non-pathogenic bacteria, as vaccine constituents in a live vaccine.

When producing the analogues of the invention by means of transformed cells, it is convenient, although far from essential, that the expression product is either exported out into the culture medium or carried on the surface of the transformed cell.

When an effective producer cell has been identified it is preferred, on the basis thereof, to establish a stable cell line which carries the vector of the invention and which expresses the nucleic acid fragment encoding the modified amyloidogenic polypeptide. Preferably, this stable cell line secretes or carries the analogue of the invention, thereby facilitating purification thereof.

In general, plasmid vectors containing replicon and control sequences which are derived from species compatible with the host cell are used in connection with the hosts. The vector ordinarily carries a replication site, as well as marking sequences which are capable of providing phenotypic selection in transformed cells. For example, *E. coli* is typically transformed using pBR322, a plasmid derived from an *E. coli* species (see, e.g., Bolivar *et al.*, 1977). The pBR322 plasmid contains

genes for ampicillin and tetracycline resistance and thus provides easy means for identifying transformed cells. The pBR plasmid, or other microbial plasmid or phage must also contain, or be modified to contain, promoters which can be used by the prokaryotic microorganism for expression.

Those promoters most commonly used in recombinant DNA construction include the B-lactamase (penicillinase) and lactose promoter systems (Chang *et al.*, 1978; Itakura *et al.*, 1977; Goeddel *et al.*, 1979) and a tryptophan (trp) promoter system (Goeddel *et al.*, 1979; EP-A-0 036 776). While these are the most commonly used, other microbial promoters have been discovered and utilized, and details concerning their nucleotide sequences have been published, enabling a skilled worker to ligate them functionally with plasmid vectors (Siebwenlist *et al.*, 1980). Certain genes from prokaryotes may be expressed efficiently in *E. coli* from their own promoter sequences, precluding the need for addition of another promoter by artificial means.

In addition to prokaryotes, eukaryotic microbes, such as yeast cultures may also be used, and here the promoter should be capable of driving expression. *Saccharomyces cerevisiase*, or common baker's yeast is the most commonly used among eukaryotic microorganisms, although a number of other strains are commonly available. For expression in *Saccharomyces*, the plasmid YRp7, for example, is commonly used (Stinchcomb *et al.*, 1979; Kingsman *et al.*, 1979; Tschemper *et al.*, 1980). This plasmid already contains the trpl gene which provides a selection marker for a mutant strain of yeast lacking the ability to grow in tryptophan for example ATCC No. 44076 or PEP4-1 (Jones, 1977). The presence of the trpl lesion as a characteristic of the yeast host cell genome then provides an effec-

tive environment for detecting transformation by growth in the absence of tryptophan.

Suitable promoting sequences in yeast vectors include the promoters for 3-phosphoglycerate kinase (Hitzman *et al.*, 1980) or other glycolytic enzymes (Hess *et al.*, 1968; Holland *et al.*, 1978), such as enolase, glyceraldehyde-3-phosphate dehydrogenase, hexokinase, pyruvate decarboxylase, phosphofructokinase, glucose-6-phosphate isomerase, 3-phosphoglycerate mutase, pyruvate kinase, triosephosphate isomerase, phosphoglucose isomerase, and glucokinase. In constructing suitable expression plasmids, the termination sequences associated with these genes are also ligated into the expression vector 3' of the sequence desired to be expressed to provide polyadenylation of the mRNA and termination.

Other promoters, which have the additional advantage of transcription controlled by growth conditions are the promoter region for alcohol dehydrogenase 2, isocytochrome C, acid phosphatase, degradative enzymes associated with nitrogen metabolism, and the aforementioned glyceraldehyde-3-phosphate dehydrogenase, and enzymes responsible for maltose and galactose utilization. Any plasmid vector containing a yeast-compatible promoter, origin of replication and termination sequences is suitable.

In addition to microorganisms, cultures of cells derived from multicellular organisms may also be used as hosts. In principle, any such cell culture is workable, whether from vertebrate or invertebrate culture. However, interest has been greatest in vertebrate cells, and propagation of vertebrate in culture (tissue culture) has become a routine procedure in recent years (Tissue Culture, 1973). Examples of such useful host

cell lines are VERO and HeLa cells, Chinese hamster ovary (CHO) cell lines, and W138, BHK, COS-7 293, *Spodoptera frugiperda* (SF) cells (commercially available as complete expression systems from *i.a.* Protein Sciences, 1000 Research Parkway, Meriden, CT 06450, U.S.A. and from Invitrogen), and MDCK cell lines. In the present invention, an especially preferred cell line is S_2 available from Invitrogen, PO Box 2312, 9704 CH Groningen, The Netherlands.

Expression vectors for such cells ordinarily include (if necessary) an origin of replication, a promoter located in front of the gene to be expressed, along with any necessary ribosome binding sites, RNA splice sites, polyadenylation site, and transcriptional terminator sequences.

For use in mammalian cells, the control functions on the expression vectors are often provided by viral material. For example, commonly used promoters are derived from polyoma, Adenovirus 2, and most frequently Simian Virus 40 (SV40). The early and late promoters of SV40 virus are particularly useful because both are obtained easily from the virus as a fragment which also contains the SV40 viral origin of replication (Fiers *et al.*, 1978). Smaller or larger SV40 fragments may also be used, provided there is included the approximately 250 bp sequence extending from the *Hind*III site toward the *Bgl*I site located in the viral origin of replication. Further, it is also possible, and often desirable, to utilize promoter or control sequences normally associated with the desired gene sequence, provided such control sequences are compatible with the host cell systems.

An origin of replication may be provided either by construction of the vector to include an exogenous origin, such as may

be derived from SV40 or other viral (e.g., Polyoma, Adeno, VSV, BPV) or may be provided by the host cell chromosomal replication mechanism. If the vector is integrated into the host cell chromosome, the latter is often sufficient.

Identification of useful analogues

It will be clear to the skilled person that not all possible variants or modifications of naturally occurring APP or Aβ will have the ability to elicit antibodies in an animal which are cross-reactive with the natural form. It is, however, not difficult to set up an effective standard screen for modified amyloidogenic molecules which fulfill the minimum requirements for immunological reactivity discussed herein. Hence, it is possible to utilise a method for the identification of a modified amyloidogenic polypeptide which is capable of inducing antibodies against unmodified amyloidogenic polypeptide in an animal species where the unmodified amyloidogenic polypeptide is a (non-immunogenic) self-protein, the method comprising

- preparing, by means of peptide synthesis or genetic engineering techniques, a set of mutually distinct analogue of the invention wherein amino acids have been added to, inserted in, deleted from, or substituted into the amino acid sequence of an APP or Aβ of the animal species thereby giving rise to amino acid sequences in the set which comprise T-cell epitopes which are foreign to the animal species, or preparing a set of nucleic acid fragments encoding the set of mutually distinct analogues,

- testing members of the set of analogues or nucleic acid fragments for their ability to induce production of anti-

bodies by the animal species against the unmodified APP or Aβ, and

- identifying and optionally isolating the member(s) of the set of analogues which significantly induces antibody production against unmodified APP or Aβ in the species or identifying and optionally isolating the polypeptide expression products encoded by members of the set of nucleic acid fragments which significantly induces antibody production against unmodified APP or Aβ in the animal species.

In this context, the "set of mutually distinct modified amyloidogenic polypeptides" is a collection of non-identical analouges which have e.g. been selected on the basis of the criteria discussed above (e.g. in combination with studies of circular dichroism, NMR spectra, and/or X-ray diffraction patterns). The set may consist of only a few members but it is contemplated that the set may contain several hundred members.

The test of members of the set can ultimately be performed *in vivo*, but a number of *in vitro* tests can be applied which narrow down the number of modified molecules which will serve the purpose of the invention.

Since the goal of introducing the foreign T-cell epitopes is to support the B-cell response by T-cell help, a prerequisite is that T-cell proliferation is induced by the analogue. T-cell proliferation can be tested by standardized proliferation assays *in vitro*. In short, a sample enriched for T-cells is obtained from a subject and subsequently kept in culture. The cultured T-cells are contacted with APCs of the subject which have previously taken up the modified molecule and processed

it to present its T-cell epitopes. The proliferation of T-cells is monitored and compared to a suitable control (e.g. T-cells in culture contacted with APCs which have processed intact, native amyloidogenic polypeptide). Alternatively, proliferation can be measured by determining the concentration of relevant cytokines released by the T-cells in response to their recognition of foreign T-cells.

Having rendered highly probable that at least one analogue of either type of set is capable of inducing antibody production against APP or Aβ, it is possible to prepare an immunogenic composition comprising at least one analouge which is capable of inducing antibodies against unmodified APP or Aβ in an animal species where the unmodified APP or Aβ is a self-protein, the method comprising admixing the member(s) of the set which significantly induces production of antibodies in the animal species which are reactive with the APP or Aβ with a pharmaceutically and immunologically acceptable carrier and/or vehicle and/or diluent and/or excipient, optionally in combination with at least one pharmaceutically and immunologically acceptable adjuvant.

The above-described tests of polypeptide sets are conveniently carried out by initially preparing a number of mutually distinct nucleic acid sequences or vectors of the invention, inserting these into appropriate expression vectors, transforming suitable host cells (or host animals) with the vectors, and effecting expression of the nucleic acid sequences of the invention. These steps can be followed by isolation of the expression products. It is preferred that the nucleic acid sequences and/or vectors are prepared by methods comprising exercise of a molecular amplification technique such as PCR or by means of nucleic acid synthesis.

Specific amyloidogenic targets

In addition to the proteins most often associated with Alzheimer's, APP, ApoE4 and Tau, there is long list of other proteins that have somehow been linked to AD, either by their direct presence in plaques or tangles of AD brains or by their apparent genetic association with increased risk of developing AD. Most, if not all, of these antigens are together with the above-discussed Aβ, APP, presenilin and ApoE4, putative target proteins in certain embodiment of the present invention. These putative targets are already discussed thoroughly in WO 01/62284. Hence, these putative targets will only be mentioned briefly here, whereas a more thorough background discussion can be be found in WO 01/62282 which is hereby incorporated by reference herein:

Alpha1-antichymotrypsin (ACT); Alpha2-macroglobulin; ABAD (Aβ-peptide binding alcohol dehydrogenase); APLP1 and -2 (amyloid precursor like protein 1 and -2); AMY117; Bax; Bcl-2; Bleomycin hydrolase; BRI/ABRI; Chromogranin A; Clusterin/apoJ; CRF (corticotropin releasing factor) binding protein; EDTF (endothelial-derived toxic factor); Heparan sulfate proteoglycans; Human collapsin response mediator protein-2; Huntingtin (Huntington's disease protein); ICAM-I; IL-6; Lysosome-associated antigen CD68; P21 ras; PLC-delta 1 (phospholipase C isoenzyme delta 1); Serum amyloid P component (SAP); Synaptophysin; Synuclein (alpha-synuclein or NACP); and TGF-b1 (transforming growth factor b1).

The presently described means and methods for down-regulation of APP or Aβ can be combined with therapies, e.g. active specific immunotherapy, against any of these other amyloidogenic polypeptides.

Apart from Alzheimer's disease, also cerebral amyloid angiopathy is a disease that would be a suitable target for the presently disclosed technology.

It is contemplated that most methods for immunizing against APP or Aβ should be restricted to immunization giving rise to antibodies cross-reactive with the native APP or Aβ. Nevertheless, in some cases it will be of interest to induce cellular immunity in the form of CTL responses against cells which present MHC Class I epitopes from the amyloidogenic polypeptides - this can be expedient in those cases wherein reduction in the number of cells producing APP or Aβ does not constitute a serious adverse effect. In such cases where CTL responses are desired it is preferred to utilise the teachings of Applicant's WO 00/20027. The disclosures of these two documents are hereby incorporated by reference herein.

IMMUNOGEN CARRIERS

Molecules comprising a T helper epitope and APP or Aβ peptides representing or including B-cell epitopes linked covalently to a non-immunogenic polymer molecule acting as a vehicle, e.g. a multivalent activated poly-hydroxypolymer, will, as mentioned above, function as a vaccine molecule that only contains the immunologically relevant parts, can be obtained, and are interesting embodiments in variants d and e disclosed above. Promiscuous or so-called universal T-helper epitopes can be used if e.g. the target for the vaccine is a self-antigen such as APP or Aβ. Furthermore, elements that enhance the immunological response could be also co-coupled to the vehicle and thereby act as an adjuvant. Such elements could be mannose, tuftsin, muramyl dipeptide, CpG motifs etc. In that case, sub-

sequent adjuvant formulation of the vaccine product might be unnecessary and the product could be administered in pure water or saline.

By coupling cytotoxic T cell (CTL) epitopes together with the T-helper epitopes it will also be possible to generate CTL's specific for the antigen from which the CTL epitope was derived. Elements that promote uptake of the product to the cytosol, such as mannose, of the APC, e.g. a macrophage, could also be co-coupled to the vehicle together with the CTL- and the T helper epitope and enhance the CTL response.

The ratio of B-cell epitopes and T-helper epitopes (P2 and P30) in the final product can be varied by varying the concentration of these peptides in the synthesis step. As mentioned above, the immunogenic molecule can be tagged with e.g. mannose, tuftsin, CpG-motifs or other immune stimulating substances (described herein) by adding these, if necessary by using e.g. aminated derivatives of the substances, to the carbonate buffer in the synthesis step.

If an insoluble activated polyhydroxy polymer is used to combine the peptides containing the APP or Aβ B-cell epitope and the T-helper epitopes it can, as mentioned above be performed as a solid phase synthesis and the final product can be harvested and purified by wash and filtration. The elements to be coupled to a tresyl activated polyhydroxypolymer (peptides, tags etc) can be added to the polyhydroxypolymer at low pH, e.g. pH 4-5, and allowed to be equally distributed in the "gel" by passive diffusion. Subsequently, the pH can be raised to pH 9-10 to start the reaction of the primary amino groups on the peptides and tags to the tresyl groups on the polyhydroxy polymer. After coupling of peptides and e.g. immune

stimulating elements the gel is grinded to form particles of suitable size for immunization.

Such an immunogen therefore comprises

a) at least one first amino acid sequence derived from APP or Aβ, wherein the at least one first amino acid sequence contains at least one B-cell and/or at least one CTL epitope, and

b) at least one second amino acid sequence that includes a foreign T helper cell epitope,

wherein each of the at least first and at least second amino acid sequences are coupled to a pharmaceutically acceptable activated polyhydroxypolymer carrier.

In order for the amino acid sequences to couple to the polyhydroxypolymer it is normally necessary to "activate" the polyhydroxypolymer with a suitable reactive group that can form the necessary link to the amino acid sequences.

The term "polyhydroxypolymer" is intended to have the same meaning as in WO 00/05316, *i.e.* the polyhydroxypolymer can have exactly the same characteristics as is specifically taught in that application. Hence, the polyhydroxypolymer can be water soluble or insoluble (thus requiring different synthesis steps during preparation of the immunogen). The polyhydroxypolymer can be selected from naturally occurring polyhydroxy compounds and synthetic polyhydroxy compounds.

Specific and preferred polyhydroxypolymers are polysaccharides selected from acetan, amylopectin, gum agar-agar, agarose, alginates, gum Arabic, carregeenan, cellulose, cyclodextrins,

dextran, furcellaran, galactomannan, gelatin, ghatti, glucan, glycogen, guar, karaya, konjac/A, locust bean gum, mannan, pectin, psyllium, pullulan, starch, tamarine, tragacanth, xanthan, xylan, and xyloglucan. Dextran is especially preferred.

However, the polyhydroxypolymer can also be selected from highly branched poly(ethyleneimine)(PEI), tetrathienylene vinylene, Kevlar (long chains of poly-paraphenyl terephtalamide), Poly(urethanes), Poly(siloxanes), polydimethylsiloxane, silicone, Poly(methyl methacrylate) (PMMA), Poly(vinyl alcohol), Poly(vinyl pyrrolidone), Poly(2-hydroxy ethyl methacrylate), Poly(N-vinyl pyrrolidone), Poly(vinyl alcohol), Poly(acrylic acid), Polytetrafluoroethylene (PTFE), Polyacrylamide, Poly(ethylene-co-vinyl acetate), Poly(ethylene glycol) and derivatives, Poly(methacrylic acid), Polylactides (PLA), Polyglycolides (PGA), Poly(lactide-co-glycolides) (PLGA), Polyanhydrides, and Polyorthoesters.

The (weight) average molecular weight of the polyhydroxypolymer in question (i.e. before activation) is typically at least 1,000, such as at least 2,000, preferably in the range of 2,500-2,000,000, more preferably in the range of 3,000-1,000,000, in particular in the range of 5,000-500,000. It has been shown in the examples that polyhydroxypolymers having an average molecular weight in the range of 10,000-200,000 are particularly advantageous.

The polyhydroxypolymer is preferably water soluble to an extent of at least 10 mg/ml, preferably at least 25 mg/ml, such as at least 50 mg/ml, in particular at least 100 mg/ml, such as at least 150 mg/ml at room temperature. It is known that dextran, even when activated as described herein, fulfils the requirements with respect to water solubility.

For some of the most interesting polyhydroxypolymers, the ratio between C (carbon atoms) and OH groups (hydroxy groups) of the unactivated polyhydroxypolymers (i.e. the native polyhydroxypolymer before activation) is in the range of 1.3 to 2.5, such as 1.5-2.3, preferably 1.6-2.1, in particular 1.85-2.05. Without being bound to any specific theory, it is believed that such as a C/OH ratio of the unactivated polyhydroxypolymer represents a highly advantageous level of hydrophilicity. Polyvinylalcohol and polysaccharides are examples of polyhydroxypolymers which fulfil this requirement. It is believed that the above-mentioned ratio should be roughly the same for the activated polyhydroxypolymer as the activation ratio should be rather low.

The term "polyhydroxypolymer carrier" is intended to denote the part of the immunogen that carries the amino acid sequences. As a general rule, the polyhydroxypolymer carrier has its outer limits where the amino acid sequences can be cleaved of by a peptidase, e.g. in an antigen presenting cell that is processing the immunogen. Hence, the polyhydroxypolymer carrier can be the polyhydroxypolymer with an activation group, where the bond between the activation group and the amino acid sequence is cleavable by a peptidase in an APC, or the polyhydroxypolymer carrier can be a polyhydroxypolymer with activation group and e.g. a linker such as a single L-amino acid or a number of D-amino acids, where the last part of the linker can bond to the amino acid sequences and be cleaved by a peptidase in an APC.

As mentioned above, the polyhydroxypolymers carry functional groups (activation groups), which facilitate the anchoring of peptides to the carrier. A wide range of applicable functional groups are known in the art, e.g. tresyl (trifluoroethylsul-

phonyl), maleimido, p-nitrophenyl cloroformate, cyanogenbromide, tosyl (p-toluenesulfonyl), triflyl (trifluoromethanesulfonyl), pentafluorobenzenesulfonyl, and vinyl sulphone groups. Preferred examples of functional groups within the present invention are tresyl, maleimido, tosyl, triflyl, pentafluorobenzenesulfonyl, p-nitrophenyl cloroformate, and vinylsulphone groups, among which tresyl, maleimido, and tosyl groups are particularly relevant.

Tresyl activated polyhydroxypolymers can be prepared using tresyl chloride as described for activation of dextran in Example 1 in WO 00/05316 or as described in Gregorius et al., J. Immunol. Meth. 181 (1995) 65-73.

Maleimido activated polyhydroxypolymers can be prepared using *p*-maleimidophenyl isocyanate as described for activation of dextran in Example 3 of WO 00/05316. Alternatively, maleimido groups could be introduced to a polyhydroxypolymer, such as dextran, by derivatisation of a tresyl activated polyhydroxypolymer (such as tresyl activated dextran (TAD)) with a diamine compound (generally $H_2N-C_nH_{2n}-NH_2$, where n is 1-20, preferably 1-8), e.g. 1,3-diaminopropane, in excess and subsequently react the amino groups introduced in TAD with reagents such as succinimidyl 4-(N-maleimidomethyl)cyclohexane-1-carboxylate (SMCC), sulfo-succinimidyl 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate (sulfo-SMCC), succinimidyl 4-(*p*-maleimidophenyl)butyrate (SMPB), sulfo-succinimidyl 4-(*p*-maleimidophenyl)butyrate (sulfo-SMPB), N-γ-maleimidobutyryloxy-succinimide ester (GMBS) or N-γ-maleimidobutyryloxy-sulfosuccinimide ester. Although the different reagents and routes for activation formally results in slightly different maleimide activated products with respect to the linkage between the maleimide functionality and the remainder of the parent

hydroxy group on which activation is performed, all and every are considered as "maleimide activated polyhydroxypolymers".

Tosyl activated polyhydroxypolymers can be prepared using tosyl chloride as described for activation of dextran in Example 2 in WO 00/05316. Triflyl and pentafluorobenzenesulfonyl activated polyhydroxypolymers are prepared as the tosyl or tresyl activated analogues, e.g. by using the corresponding acid chlorides.

Cyanogenbromide activated polyhydroxypolymer can be prepared by reacting the polyhydroxypolymer with cyanogenbromide using conventional methods. The resulting functional groups are normally cyanate esters with two hydroxy groups of the polyhydroxypolymer.

The degree of activation can be expressed as the ratio between the free hydroxy groups and the activation groups (i.e. functionalised hydroxy groups). It is believed that a ratio between the free hydroxy groups of the polyhydroxypolymer and the activation groups should be between 250:1 and 4:1 in order to obtain an advantageous balance between the hydrophilicity and the reactivity of the polyhydroxypolymer. Preferably the ratio is between 100:1 and 6:1, more preferably between 60:1 and 8:1, in particular between 40:1 and 10:1.

Especially interesting activated polyhydroxypolymers for use in the method for producing the generally applicable immunogen according to the invention are tresyl, tosyl and maleimido activated polysaccharides, especially tresyl activated dextran (TAD), tosyl activated dextran (TosAD), and maleimido activated dextran (MAD).

It is preferred that the bond between the polyhydroxypolymer carrier and the amino acid sequences attached thereto are cleavable by a peptidase, e.g. as a peptidase active in the processing of antigens in an APC. It is therefore preferred that the at least first and at least second amino acid sequences are coupled to the activated polyhydroxypolymer carrier via an amide bond or a peptide bond. It is especially preferred that the at least first and at least second amino acid sequences each provide for the nitrogen moiety of their respective amide bond.

The polyhydroxypolymer carrier may be substantially free of amino acid residues, necessitating that the activation group provides for part of a peptidase cleavable bond, but as mentioned above, the carrier may also simply include a spacer including at least one L-amino acid. Nevertheless, the at least first and at least second amino acid sequences are normally bound to the activated version of the polyhydroxypolymer via the nitrogen at the N-terminus of the amino acid sequence.

The above-described generally applicable immunogen of the present invention can be used in immunization methods essentially as described herein for polypeptide vaccines. That is, all disclosures relating to dosages, mode of administration and formulation of polypeptide vaccines for down-regulating the amyloidogenic polypeptides discussed herein apply *mutatis mutandis* to the generally applicable immunogens.

GENERALLY APPLICABLE SAFE VACCINATION TECHNOLOGY

As discussed above, one preferred embodiment of the present invention entails the use of variants of amyloidogenic polypeptides that are incapable of providing self-derived T_H epi-

topes that may drive an immune response against the amyloidogenic polypeptide.

However, it is believed by the present inventors that this strategy for designing anti-self vaccines and for effecting anti-self immunity, is a generally applicable technology that is inventive in its own right. It should prove especially suited in cases where the self-antigen it is sought to down-regulate is sufficiently abundant in the body so that it is possible that self-stimulation of an immune response could happen. Hence, all disclosures above of this embodiment insofar as it relates to the provision of an anti-self immune response against APP or Aβ applies mutatis mutandis to immunization against other self-polypeptides, especially those that are present in sufficient amounts for them to maintain the immune response in the form of an uncontrolled autoimmune condition because autologous T_H epitopes of the relevant self-polypeptide are driving the immune response.

EXAMPLE 1

The Auto Vaccination approach for Immunizing against AD

The fact that Aβ protein knock out mice does not show any abnormalities or adverse side effects, suggest that removal or lowering the amounts of Aβ will be safe, Zheng H. (1996).

Published experiments where transgenic animals are immunized against the transgenic human Aβ protein suggest that if it was possible to break the self tolerance, down-regulation of Aβ could be obtained by auto-reactive antibodies. These experiments further suggest that such down regulation of Aβ poten-

tially would both prevent the formation of plaques, and even clear already formed Aβ plaques from the brain, cf. Schenk et al. (1999). But, traditionally it is not possible to raise antibodies against self-proteins.

The published data does thus not provide the means for breaking true self-tolerance towards true self-proteins. Nor does the data provide information on how to ensure that the immune reaction is directed solely or predominantly towards the Aβ deposits, and not towards the cell membrane bound Aβ precursor protein (APP), if this is deemed necessary. An immune response generated using the existing technology would presumably generate an immune response towards self-proteins in an unregulated way so unwanted and excessive auto-reactivity towards parts the Aβ protein may be generated. Hence, using existing immunization strategies will most likely be unable to generate strong immune responses towards self-proteins and will furthermore be unsafe due to potential strong cross-reactivity towards membrane bound APP which is present on a large number of cells in the CNS.

The present invention provides the means of effectively generating a strong regulated immune response towards true self-proteins which potentially could form plaques and cause serious disease in the CNS or in other compartments of the body. A safe and efficacious human Aβ protein therapeutic vaccine will be developed by using this technology for the treatment of AD.

In light of this, it is possible to anticipate that AD, a disease predicted to cripple the health care system in the next century, could be cured, or such vaccines described could at least constitute an effective therapeutical approach for

treatment of the symptoms and progression of this disease. This technique represents a entirely new immunological approach to blocking amyloid deposition in AD and other neurologic diseases as well.

In the following table, 35 contemplated constructs are indicated. All positions given in the table are relative to the starting Methionine of APP (first amino acid in SEQ ID NO: 2) and include both the starting and ending amino acid, e.g. the 672 - 714 fragment includes both amino acid 672 and 714. The starting and ending positions for P2 and P30 indicate that the epitope substitutes a part of the APP fragment at the positions indicated (both positions included in the substitution) - in most constructs, the introduced epitopes substitutes a fragment of the length of the epitope. The asterisks in the table have the following meaning:

*) Only one position for P2 and P30 indicates that the epitope has been *inserted* into the APP derivative at the position indicated (the epitope begins at the amino acid C-terminally adjacent to the given position).

**) Construction 34 contains three identical APP fragments separated by P30 and P2, respectively.

***) Construction 35 contains nine identical APP fragments separated by alternating P30 and P2 epitopes.

APP AutoVac constructions

Var. No.	Start of APP segment relative to aa 1 of APP	End of APP segment relative to aa 1 of APP	Position of P2 epitope relative to aa 1 of APP	Position of P30 epitope relative to aa 1 of APP	Molecule length
1	630	770	656 - 670	635 - 655	141
2	630	714	656 - 670	635 - 655	85
3	672	770	735 - 749	714 - 728	99
4	672	770		714 - 728	99
5	672	770	714 - 728		99
6	672	770	723*	723*	135
7	672	770		723*	120
8	672	770	723*		114
9	672	714		672*	64
10	672	714		714*	64
11	672	714	672*		58
12	672	714	714*		58
13	672	714	714*	672*	79
14	672	714	680 - 694		43
14	672	714	685 - 799		43
16	672	714	690 - 704		43
17	672	714	695 - 709		43
18	672	714		675 - 695	43
19	672	714		680 - 700	43
20	672	714		685 - 705	43
21	672	714		690 - 710	43
22	672	714	680*	680*	79
23	672	714	690*	690*	79
24	672	714	700*	700*	79
25	672	714	710*	710*	79
26	672	714		680*	64
27	672	714		690*	64
28	672	714		700*	64
29	672	714		710*	64
30	672	714	680*		58
31	672	714	690*		58
32	672	714	700*		58
33	672	714	710*		58
34	672	714	After rep. 1**	After rep. 2**	165
35	672	714	34 x 3*	34 x 3***	165

The part of APP, against which it most interesting to generate a response, is the 43 amino acid Aβ core peptide (Aβ-43, corresponding to SEQ ID NO: 2, residues 672-714) that is the main constituent of amyloid plaques in AD brains. This APP fragment is part of all constructions listed above.

Variants 1 and 2 comprise a portion of APP upstream of Aβ-43 where the model epitopes P2 and P30 have been placed. Variants 1 and 3-8 all comprise the C-100 fragment which has been shown to be neurotoxic - the C-100 fragment corresponds to amino acid residues 714-770 of SEQ ID NO: 2. In variants 3-5 the epitopes substitutes a part of the C-100 fragment while the in variants 6-8 have been inserted into C-100.

Variants 9-35 contain only the core Aβ-43 protein. In variants 9-13, P2 and P30 are fused to either end of Aβ-43; in 14-21 P2 and P30 substitutes part of Aβ-43; in 22-33 P2 and P30 are inserted into Aβ-43; 34 contains three identical Aβ-43 fragments spaced by P30 and P2, respectively; 35 contains 9 Aβ-43 repeats spaced by alternating P2 and P30 epitopes.

Truncated parts of the above-discussed Aβ-43 protein can also be employed in immunogenic analogues according to the present invention. Especially preferred are the truncates Aβ(1-42), Aβ(1-40), Aβ(1-39), Aβ(1-35), Aβ(1-34), Aβ(1-34), Aβ(1-28), Aβ(1-12), Aβ(1-5), Aβ(13-28), Aβ(13-35), Aβ(17-28), Aβ(25-35), Aβ(35-40), Aβ(36-42), and Aβ(35-42) (where the numbers in the parentheses indicate the amino acid stretches of Aβ-43 that constitute the relevant fragment - Aβ(35-40) is e.g. identical to amino acids 706-711 in SEQ ID NO: 2). All these variants with truncated parts of Aβ-43 can be made with the Aβ fragments

described herein, in particular with variants 9, 10, 11, 12, and 13.

In some cases, it is preferred that the Aβ-43 or fragments thereof are mutated. Especially preferred are substitution variants where the methionine in position 35 in Aβ-43 has been substituted, preferably with leucine or isoleucine, or simply deleted. Especially preferred analogues contain one single methionine that is located in the C-terminus, either because it is naturally occurring in the amyloidogenic polypeptide or foreign T_H epitope, or because it has been inserted or added. Hence, it also preferred that the part of the analogue that includes the foreign T_H epitope is free from methionine, except from the possible C-terminal location of a methionine.

In fact, it is generally preferred that all analogues of APP or Aβ that are used according to the present invention share the characteristic of merely including one single methionine that is positioned as the C-terminal amino acid in the analogue and that other methionines in either the amyloidogenic polypeptide or the foreign T_H epitope are deleted or substituted for another amino acid.

One further interesting mutation is a deletion or substitution of the phenylalanine in position 19 in Aβ-43, and it is especially preferred that the mutation is a substitution of this phenylalanine residue with a proline.

The following table sets forth a group of especially preferred constructs that operate with truncates or mutations of Aβ-43:

Variant No.	Aβ segment used in molecule relative to aa 1 of Aβ (1-42/43)	Position of Aβ segment relative to aa 1 of molecule	Position of P2 epitope relative to aa 1 of molecule	Position of P30 epitope relative to aa 1 of molecule	Total length of molecule (aa)
36	1-28	22-49	50-64	1-21	64
37	1-12 (a) + 13-28 (b)	1-12 (a) + 49-64 (b)	34-48	13-33	64
38	1-12 (x 3)	1-12, 34-45, 61-72	46-60	13-33	72
39	13-28 (x 3)	1-16, 38-53, 69-84	54-68	17-37	84
40	1-12 (a) + 13-35 (b) + 36-42 (c)	1-12 (a) + 34-56 (b) + 72-78 (c)	57-71	13-33	78
41	1-28 (x 3)	1-28, 50-77, 93-120	78-92	29-49	120
42	1-43 (F19P/M35K)	1-43	65-79	44-64	79

In this table, the Aβ segment used in the molecule is indicated by amino acid numbers relative to aa 1 of the Aβ(1-42/43) molecule, i.e. 1-28 means that fragment 1-28 of Aβ(1-42/43) is used in the molecule. If two or more different segments are used, both are indicated in the table, i.e. 1-12 (a) + 13-28 (b) means that both fragment 1-12 and fragment 13-28 of Aβ(1-42/43) are used in the molecule.

Also, if the same segment is present in more than one copy in the construction it is indicated in the table, i.e. 1-12 (x3) shows that fragment 1-12 of Aβ(1-42/43) is present in three copies in the construction.

Further, the position of the Aβ segment in the molecule is shown by amino acid positions relative to the first amino acid of the molecule, i.e. 22-49 shows that the Aβ fragment in question is positioned from amino acid 22 to amino acid 49 in the molecule, both positions included. Positions of the P2 and P30 epitopes are indicated equivalently. If two or more different Aβ fragments are used in the molecule, their positions are all shown, i.e. 1-12 (a) + 49-64 (b) means that fragment (a) is

positioned from aa 1-12 in the molecule and fragment (b) from aa 49-64.

Moreover, if more than one copy of the same fragment is present in the molecule, positions for all copies are shown, i.e. 1-12, 34-45, 61-72 shows that the three copies of the Aβ fragment are placed from position 1-12, 34-45 and 61-72, respectively, in the molecule.

Finally, the total length indication of each molecule includes both the Aβ fragment(s) and the P2 and P30 epitopes.

Variant 42 contains two amino acid substitutions at positions 19 (phe to pro) and 35 (met to lys) as it is indicated in the column showing the Aβ fragments.

See Fig. 1 and the tables above for details on particular points for introduction of the foreign T-cell epitopes.

One further type of construct is especially preferred. Since one goal of the present invention is to avoid destruction of the cells producing APP whereas removal of Aβ is desired, it seems feasible to prepare autovaccine constructs comprising only parts of Aβ which are not exposed to the extracellular phase when present in APP. Thus, such constructs would need to contain at least one B-cell epitope derived from the amino acid fragment defined by amino acids 700-714 in SEQ ID NO: 2. Since such a short polypeptide fragment is predicted to be only weakly immunogenic it is preferred that such an autovaccine construct consists of several copies of the B-cell epitope, e.g. in the form of a construct having the structure shown in Formula I in the detailed disclosure of the present invention, cf. above. In that version of Formula I, the terms

amyloid$_{e1}$-amyloid$_{ex}$ are x B-cell epitope containing amino acid sequences derived from amino acids 700-714 of SEQ ID NO: 2. A preferred alternative is the above-detailed possibility of coupling the amyloidogenic (poly)peptide and the selected foreign T-helper epitope to via an amide bond to a polysaccharide carrier molecule – in this way multiple presentaions of the "weak" epitope constituted by amino acids 700-714 of SEQ ID NO: 2 become possible, and it also becomes possible to select an optimum ratio between B-cell and T-cell epitopes.

EXAMPLE 2

Immunisation of transgenic mice with Aβ and modified proteins according to the invention

Construction of the hAB43+-34 encoding DNA. The hAB43+-34 gene was constructed in several steps. First a PCR fragment was generated with primers ME#801 (SEQ ID NO: 10) and ME#802 (SEQ ID NO: 11) using primer ME#800 (SEQ ID NO: 9) as template. ME#800 encodes the human abeta-43 fragment with E. coli optimised codons. ME#801 and 802 adds appropriate restriction sites to the fragment.

The PCR fragment was purified, digested with *Nco*I and *Hind*III, purified again and cloned into *Nco*I-*Hind*III digested and purified pET28b+ *E. coli* expression vector. The resulting plasmid encoding wildtype human Aβ-43 is named pAB1.

In the next step the T-helper epitope, P2, is added to the C-terminus of the molecule. Primer ME#806 (SEQ ID NO: 12) contains the sequence encoding the P2 epitope, thus generating a fusion of P2 and Abeta-43 by the PCR reaction.

The cloning was performed by making a PCR fragment with primers ME#178 (SEQ ID NO: 8) and ME#806 using pAB1 as template. The fragment was purified, digested with *Nco*I and *Hind*III, purified again and cloned into an *Nco*I-*Hind*III digested and purified pET28b+ vector. The resulting plasmid is called pAB2.

In an analogous manner, another plasmid was made harbouring the Aβ-43 encoding sequence with another T helper epitope, P30, added to the N-terminus. This was done by making a PCR fragment with primers ME#105 (SEQ ID NO: 7) and ME#807 (SEQ ID NO: 13) using pAB1 as template.

The fragment was purified, digested with *Nco*I and *Hind*III, purified again and cloned into an *Nco*I-*Hind*III digested and purified pET28b+ vector. The resulting plasmid is called pAB3.

In the third step, a second Aβ-43 repeat is added C-terminally to the P2 epitope of plasmid pAB2 by primer ME#809 (SEQ ID NO: 14). ME#809 at the same time creates a *Bam*HI site immediately after the Aβ-43 repeat. A PCR fragment was made with primers ME#178 and ME#809 using pAB2 as template. The fragment was digested with *Nco*I and *Hind*III, purified and cloned into *Nco*I-*Hind*III digested and purified pET28b+ vector. This plasmid is named pAB4.

Finally, the P30 epitope – Aβ-43 repeat sequence from pAB3 was cloned into pAB4 plasmid. This was done by making a PCR fragment with primers ME#811 (SEQ ID NO: 16) and ME#105 using pAB3 as template. The fragment was purified and used as primer in a subsequent PCR with ME#810 (SEQ ID NO: 15) using pAB3 as template. The resulting fragment was purified, digested with *Bam*HI and *Hind*III and cloned into *Bam*HI-*Hind*III digested and

purified pAB4 plasmid. The resulting plasmid, pAB5, encodes the hAB43+-34 molecule.

All PCR and cloning procedures were done essentially as described by Sambrook, J., Fritsch, E.F. & Maniatis, T. 1989 "Molecular cloning: a laboratory manual". 2nd. Ed. Cold Spring Harbor Laboratory, N.Y.

For all cloning procedures *E. coli* K-12 cells, strain Top-10 F' (Stratagene, USA), were used. The pET28b+ vector was purchased from Novagen, USA. All primers were synthesised at DNA Technology, Denmark.

Expression and purification of hAB43+-34. The hAB43+-34 protein encoded by pAB5 was expressed in BL21-Gold (Novagen) *E. coli* cells as described by the suppliers of the pET28b+ system (Novagen).

The expressed hAB43+-34 protein was purified to more than 85% purity by washing of inclusion bodies followed by cation-exchange chromatography using a BioCad purification workstation (PerSeptive Biosystems, USA) in the presence of 6 M urea. The urea was hereafter removed by stepwise dialysis against a solution containing decreasing amounts of urea. The final buffer was 10 mM Tris, pH 8.5.

Immunisation study. Mice transgenic for human APP (Alzheimer's precursor protein) were used for the study. These mice, called TgRND8+, express a mutated form of APP that results in high concentration of Aβ-40 and Aβ-42 in the mouse brains (Janus, C. *et. al.*)

The mice (8-10 mice per group) were immunised with either Abeta-42 (SEQ ID NO: 2, residues 673-714, synthesised by means

of a standard Fmoc strategy) or the hAB43+-34 variant (construct 34 in the table in Example 1, recombinantly produced) four times at two-week intervals. Doses were either 100 mg for Aβ or 50 mg for hAB43+-34. Mice were bled at day 43 (after three injections) and after day 52 (after four injections) and the sera were used to determine the level of anti-Aβ-42 specific titres using a direct Aβ-42 ELISA.

The following tabel shows the mean relative anti-Abeta-42 titres.

Immunogen	Day 43 (after 3 immunizations)	Day 52 (after 4 immunizations)
Aβ-42	4000	3000
hAB43+-34	16000	23000

As will be clear, the antibody titers obtained when immunizing with the hAB43+-34 Aβ variant are approximately 4 times and 7.5 times higher after 3 and 4 immunizations, respectively, than the titers obtained when using the unaltered wild-type Aβ-42 as an immunogen. This fact is put further in perspective, when considering the fact that the amount of variant used for immunization was only 50% of the amount of wild-type sequence used for immunization.

EXAMPLE 3

Synthesis of an Aβ Peptide Copolymer Vaccine using activated poly-hydroxypolymer as the cross-linking agent.

Introduction. A traditional conjugate vaccine consists of a (poly)peptide coupled covalently to a carrier protein. The peptide contains the B-cell epitope(s) and the carrier protein provides T-helper epitopes. However, most of the carrier pro-

tein will normally be irrelevant as a source for T-helper epitopes, since only a minor part of the total sequence contains the relevant T-helper epitopes. Such epitopes can be defined and synthesized as peptides of e.g. 12-15 amino acids. If these peptides are linked covalently to peptides containing the B-cell epitopes, e.g. via a multivalent activated poly-hydroxypolymer, a vaccine molecule that only contains the relevant parts can be obtained. It is further possible to provide a vaccine conjugate that contains an optimized ratio between B-cell and T-cell epitopes.

Synthesis of the acticated poly-hydroxypolymer. Poly-hydroxy-polymers such as dextran, starch, agarose etc. can be activated with 2,2,2-trifluoroethanesulfonyl chloride (tresyl chloride), either by means of a homogenous synthesis (dextran) dissolved in N-methylpyrrolidinone (NMP) or by means of a heterogeneous synthesis (starch, agarose, cross-linked dextran) in e.g. acetone.

225 ml dry N-methyl pyrrolidinone (NMP) is added under dry conditions to freeze dried, water-soluble dextran (4.5 g, 83 mmol, clinical grade, Mw(avg) 78000) in a 500 ml round bottom flask supplied with a magnet for stirring. The flask is placed in a 60°C oil bath with magnetic stirring. The temperature is raised to 92°C over a period of 20 min. When the dextran is dissolved the flask is immediately removed from the oil bath and the temperature in the bath is lowered to 40°C. The flask is placed into the oil bath agaom, still with magnetic stirring, and tresyl chloride (2.764 ml, 25 mmol) is added drop-wise. After 15 min, dry pyridine (anhydrous, 2.020 ml, 25 mmol) is added drop-wise. The flask is removed from the oil bath and stirred for 1 hour at room temperature. The product (Tresyl Activated Dextran, TAD) is precipitated in 1200 ml cold ethanol

(99.9%). The supernatant is decanted and the precipitate is harvested in 50 ml polypropylene tubes in a centrifuge at 2000 rpm. The precipitate is dissolved in 50 ml 0.5% acetic acid, dialyzed 2 times against 5000 ml 0.5% acetic acid and freeze dried. TAD can be stored as a freeze dried powder at -20°C.

An insoluble poly-hydroxypolymer, such as agarose or croos-linked dextran can be tresyl activated by making a suspension of the poly-hydroxypolymer in e.g. acetone and perform the synthesis as a solid phase synthesis. The activated poly-hydroxypolymer can be harvested by filtration. Suitable methods are reported in e.g. Nilsson K and Mosbach K (1987), Methods in Enzymology **135**, p. 67, and in Hermansson GT *et al.* (1992), in "Immobilized Affinity Ligand Techniques", Academic Press, Inc., p. 87.

Synthesis of the A Beta Peptide Copolymers Vaccines. TAD (10 mg) is dissolved in 100 µl H_2O and 1000 µl carbonate buffer, pH 9.6, containing 5 mg Aβ-42 (SEQ ID NO: 2, residues 673-714), 2.5 mg P2 (SEQ ID NO: 4) and 2.5 mg P30 (SEQ ID NO: 6) is added. The Aβ-42 and the P2 and P30 peptides all contain protected lysine groups: these are in the form of 1-(4,4-Dimethyl-2,6-dioxocyclohex-1-ylidene)ethyl (Dde) protected lysine groups. The peptides are prepared by means of a standard Fmoc strategy, where the conventional Fmoc-Lys(Boc)-OH has been substituted with Fmoc-Lys(Dde)-OH (obtained from Novabiochem , cat. no. 04-12-1121), *i.e.* the ε-amino group in lysine is protected with Dde instead of Boc.

The pH value is measured and adjusted to 9.6 using 1 M HCl. After 2.5 hours at room temperature, hydrazine from an 80% solution is added to a final hydrazine koncentration of 8% and the solution is incubated for another 30 min. at room tempera-

ture and freeze-dried immediately hereafter. The freeze-dried product is dissolved in H_2O and dialysed extensively against H_2O before the final freeze-drying.

The ratio between B-cell epitopes (Aβ) and T-helper epitopes (P2 and P30) in the final product can be varied by using different concentrations of these peptides in the synthesis step. Furhermore, the final product can be tagged with e.g. mannose (so as to target the conjugate to APCs) by adding aminated mannose to the carbonate buffer in the synthesis step.

If an insoluble activated poly-hydroxypolymer is used to combine the peptides containing the B-cell epitope and the T-helper epitopes, the coupling to the polymer can be performed as a solid phase synthesis and the final product is harvested and purified by wash and filtration.

As mentioned in the general description, the presently described approach for preparing a peptide based vaccine may be applied to any other polypeptide antigen where it would be convenient to prepare a purely synthetic peptide vaccine and where the polypeptide antigen in question provides a sufficient immunogenicity in one single peptide:

EXAMPLE 4

Synthesis Peptide Copolymer Vaccines

TAD (10 mg) is dissolved in 100 µl H_2O and 1000 µl carbonate buffer, pH 9.6, containing 1-5 mg peptide A (any immunogenic peptide of interest!), 1-5 mg P2 (diphtheria toxoid P2 epitope) and 1-5 mg P30 (diphtheria toxoid P30 epitope) is added. The pH value is measured and adjusted to 9.6 using 0.1 M HCl.

After 2.5 hours at room temperature the solution is freeze dried immediately hereafter. The freeze-dried product is dissolved in H_2O and dialysed extensively against H_2O or desalted on a gelfiltration column before the final freeze-drying. In case the peptides have lysine in the sequence the ε-amine in the lysine side chain should be protected by Dde using the Fmoc-Lys(Dde)-OH derivative in the synthesis (Gregorius and Theisen 2001, submitted). After coupling, hydrazine from an 80% solution is added to a final hydrazine concentration between 1-20% and the solution is incubated for another 30 min at room temperature, freeze dried immediately hereafter and dialysed extensively against H_2O or desalted on a gelfiltration column before the final freeze-drying. The principle is set forth in schematic form in Fig. 2.

Such immunogens have been utilised by the inventors with a short C-terminal fragment of the *Borrelia burgdorferi* protein OspC as "peptide A" and a diptheria toxoid epitope (P2 or P30) as a peptide B. The results of immunization studies with this antigen revealed that only the immunogen of the invention including the OspC fragment and a foreign diptheria epitope matching the MHC haplotype of the vaccinated mice were capable of inducing antibodies reactive with OspC in these mice. In contrast, a molecule containing only the OspC peptide was unable to induce antibody production and the same was true for a mixture of 2 immunogens where one contained the OspC and the other the epitope. It is therefore concluded that the inclusion in the same polyhydroxypolymer carrier is superior, if not essential, in order to induce antibody production against a short peptide hapten as OspC.

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CLAIMS

1. A method for *in vivo* down-regulation of amyloid precursor protein (APP) or beta amyloid (Aβ) in an animal, including a human being, the method comprising effecting presentation to the animal's immune system of an immunogenically effective amount of at least one analogue of APP or Aβ that incorporates into the same molecule at least one B-cell epitope of APP and/or Aβ and at least one foreign T-helper epitope (T_H epitope) so that immunization of the animal with the analogue induces production of antibodies against the animal's autologous APP or Aβ, wherein the analogue

a) is a polyamino acid that consists of at least one copy of a subsequence of residues 672-714 in SEQ ID NO: 2, wherein the foreign T_H epitope is incorporated by means of amino acid addition and/or insertion and/or deletion and/or substitution, wherein the subsequence is selected from the group consisting of residues 1-42, residues 1-40, residues 1-39, residues 1-35, residues 1-34, residues 1-28, residues 1-12, residues 1-5, residues 13-28, residues 13-35, residues 17-28, residues 25-35, residues 35-40, residues 36-42 and residues 35-42 of the amino acid sequence consisting of amino acid residues 673-714 of SEQ ID NO: 2; and/or

b) is a polyamino acid that contains the foreign T_H epitopes and a disrupted APP or Aβ sequence so that the analogue does not include any subsequence of SEQ ID NO: 2 that binds productively to MHC class II molecules initiating a T-cell response; and/or

c) is a polyamino acid that comprises the foreign T_H epitope and APP or Aβ derived amino acids, and comprises 1 single methionine residue located in the C-terminus of the analogue, wherein other methionine residues in APP or Aβ and in the foreign T_H epitope have been substituted or deleted, and preferably have been substituted by leucin or isoleucine; and/or

d) is a conjugate comprising a polyhydroxypolymer backbone to which is separately coupled a polyamino acid as defined in a) and/or a polyamino acid as defined in b) and/or a polyamino acid as defined in c); and/or

e) is a conjugate comprising a polyhydroxypolymer backbone to which is separately coupled 1) the foreign T_H epitope and 2) a polyamino acid selected from the group consisting of a subsequence as defined in a), a disrupted sequence of APP or Aβ as defined in b), and an APP or Aβ derived amino acid sequence that comprises 1 single methionine residue located in the C-terminus, wherein other methionine residues in APP or Aβ and in the foreign T_H epitope have been substituted or deleted, and preferably have been substituted by leucin or isoleucine.

2. The method according to claim 1, wherein a substantial fraction of B-cell epitopes of APP or Aβ are preserved in the analogue and that

- at least one first moiety is introduced which effects targeting of the analogue to an antigen presenting cell (APC) or a B-lymphocyte, and/or

- at least one second moiety is introduced which stimulates the immune system, and/or

- at least one third moiety is introduced which optimizes presentation of the analogue to the immune system.

3. The method according to claim 2, wherein the first and/or of the second and/or of the third moiety is/are attached as side groups by covalent or non-covalent binding to suitable chemical groups in the APP or Aβ sequence.

4. The method according to any one of the preceding claims, wherein the analogue comprises a fusion polypeptide.

5. The method according to any one of the preceding claims, wherein introduction of the amino acid substitution and/or deletion and/or insertion and/or addition results in a substantial preservation of the overall tertiary structure of APP or Aβ.

6. The method according to any one of the preceding claims, wherein the analogue includes duplication of at least one B-cell epitope of APP or Aβ and/or introduction of a hapten.

7. The method according to any one of the preceding claims, wherein the foreign T-cell epitope is immunodominant in the animal.

8. The method according to any one of the preceding claims, wherein the foreign T-cell epitope is promiscuous, such as a foreign T-cell epitope which is selected from a natural promiscuous T-cell epitope and an artificial MHC-II binding peptide sequence.

9. The method according to claim 8, wherein the natural T-cell epitope is selected from a Tetanus toxoid epitope such as P2 or P30, a diphtheria toxoid epitope, an influenza virus hemagluttinin epitope, and a *P. falciparum* CS epitope.

10. The method according to any one of the preceding claims, wherein the analogue comprises B-cell epitopes which are not exposed to the extracellular phase when present in a cell-bound form of the precursor polypeptide Aβ.

11. The method according to any one of the preceding claims, wherein the analogue lacks at least one B-cell epitope which is exposed to the extracellular phase when present in a cell-bound form of the precursor polypeptide.

12. The method according to any one of the preceding claims, wherein the analogue comprises at most 9 consecutive amino acids of SEQ ID NO: 2., such as at most 8, at most 7, at most 6, at most 5, at most 4, and at most 3 consecutive amino acids.

13. The method according to claim 12, wherein the analogue comprises at least one subsequence of SEQ ID NO: 2 so that each such at least one subsequence of SEQ ID NO: 2 independently consists of amino acid stretches selected from the group consisting of 9 consecutive amino acids of SEQ ID NO: 2, 8 consecutive amino acids of SEQ ID NO: 2, 7 consecutive amino acids of SEQ ID NO: 2, 6 consecutive amino acids of SEQ ID NO: 2, 5 consecutive amino acids of SEQ ID NO: 2, 4 consecutive amino acids of SEQ ID NO: 2, and 3 consecutive amino acids of SEQ ID NO: 2.

14. The method according to claim 22 or 23, wherein the consecutive amino acids begin at an amino acid residue selected from the group consisting of residue 672, 673, 674, 675, 676,

677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, and 714.

15. The method according to any one of the preceding claims, wherein presentation to the immune system is effected by having at least two copies of an Aβ derived fragment or the analogue covalently of non-covalently linked to a carrier molecule capable of effecting presentation of multiple copies of antigenic determinants.

16. The method according to any one of the preceding claims, variants d or e, wherein the polyamino acid and T_H epitope are attached to the polyhydroxypolymer by means of an amide bond.

17. The method according to any one of the preceding claims , variants d or e, wherein the the polyhydroxypolymer is a polysaccharide.

18. The method according to any one of the preceding claims, wherein the analogue has been formulated with an adjuvant which facilitates breaking of autotolerance to autoantigens.

19. The method according to any one of the preceding claims, wherein an effective amount of the analogue is administered to the animal via a route selected from the parenteral route such as the intracutaneous, the subcutaneous, and the intramuscular routes; the peritoneal route; the oral route; the buccal route; the sublinqual route; the epidural route; the spinal route; the anal route; and the intracranial route.

20. The method according to claim 19, wherein the effective amount is between 0.5 µg and 2,000 µg of the analogue.

21. The method according to any one of claims 1-14, variants a-c, wherein presentation of the analogue to the immune system is effected by introducing nucleic acid(s) encoding the analogue into the animal's cells and thereby obtaining *in vivo* expression by the cells of the nucleic acid(s) introduced.

22. The method according to claim 21, wherein the nucleic acid(s) introduced is/are selected from naked DNA, DNA formulated with charged or uncharged lipids, DNA formulated in liposomes, DNA included in a viral vector, DNA formulated with a transfection-facilitating protein or polypeptide, DNA formulated with a targeting protein or polypeptide, DNA formulated with Calcium precipitating agents, DNA coupled to an inert carrier molecule, DNA encapsulated in chitin or chitosan, and DNA formulated with an adjuvant.

23. The method according to any one of claims 19-22, which includes at least one administration/introduction per year, such as at least 2, at least 3, at least 4, at least 6, and at least 12 administrations/introductions.

24. A method for treating and/or preventing and/or ameliorating Alzheimer's disease or other diseases and conditions characterized by amyloid deposits, the method comprising down-regulating APP or Aβ according to the method of any one of the preceding claims to such an extent that the total amount of amyloid is decreased or that the rate of amyloid formation is reduced with clinical significance.

25. An analogue of APP or Aβ which is derived from an animal APP or Aβ wherein is introduced a modification which has as a result that immunization of the animal with the analogue induces production of antibodies against the animal's autologous

APP or Aβ, and wherein the analogue is as defined in any one of claims 1-17.

26. An immunogenic composition comprising an immunogenically effective amount of an analogue according to claim 25, the composition further comprising a pharmaceutically and immunologically acceptable carrier and/or vehicle and optionally an adjuvant.

27. A nucleic acid fragment which encodes an analogue according to claim 25.

28. A vector carrying the nucleic acid fragment according to claim 27, such as a vector that is capable of autonomous replication.

29. The vector according to claim 28 which is selected from the group consisting of a plasmid, a phage, a cosmid, a minichromosome, and a virus.

30. The vector according to claim 28 or 29, comprising, in the 5'→3' direction and in operable linkage, a promoter for driving expression of the nucleic acid fragment according to claim 27, optionally a nucleic acid sequence encoding a leader peptide enabling secretion of or integration into the membrane of the polypeptide fragment, the nucleic acid fragment according to claim 27, and optionally a terminator.

31. The vector according to any one of claims 28-30 which, when introduced into a host cell, is capable or incapable of being integrated in the host cell genome.

32. The vector according to claim 30 or 31, wherein the promoter drives expression in a eukaryotic cell and/or in a prokaryotic cell.

33. A transformed cell carrying the vector of any one of claims 28-32, such as a transformed cell which is capable of replicating the nucleic acid fragment according to claim 27.

34. The transformed cell according to claim 33, which is a microorganism selected from a bacterium, a yeast, a protozoan, or a cell derived from a multicellular organism selected from a fungus, an insect cell such as an S_2 or an SF cell, a plant cell, and a mammalian cell.

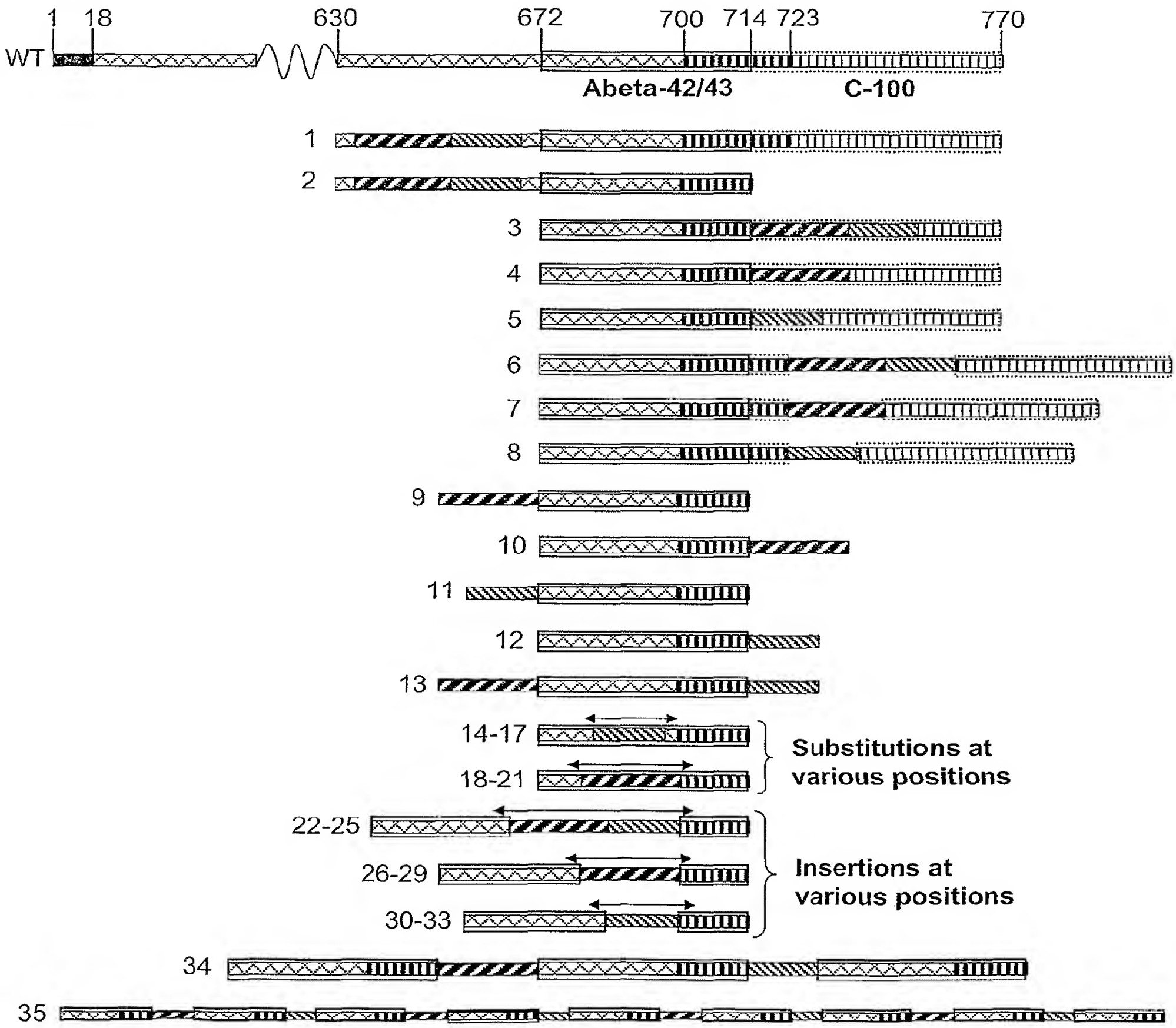
35. The transformed cell according to claim 33 or 34, which expresses the nucleic acid fragment according to claim 28, such as a transformed cell, which secretes or carries on its surface, the analogue according to claim 25.

36. The method according to any one of claims 1-14, variants a-c, wherein presentation to the immune system is effected by administering a non-pathogenic microorganism or virus which is carrying a nucleic acid fragment which encodes and expresses the analogue.

37. A composition for inducing production of antibodies against amyloid, the composition comprising

- a nucleic acid fragment according to claim 27 or a vector according to any one of claims 28-32, and
- a pharmaceutically and immunologically acceptable carrier and/or vehicle and/or adjuvant.

38. A stable cell line which carries the vector according to any one of claims 28-32 and which expresses the nucleic acid fragment according to claim 27, and which optionally secretes or carries the analogue according to claim 25 on its surface.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Insertions at various positions
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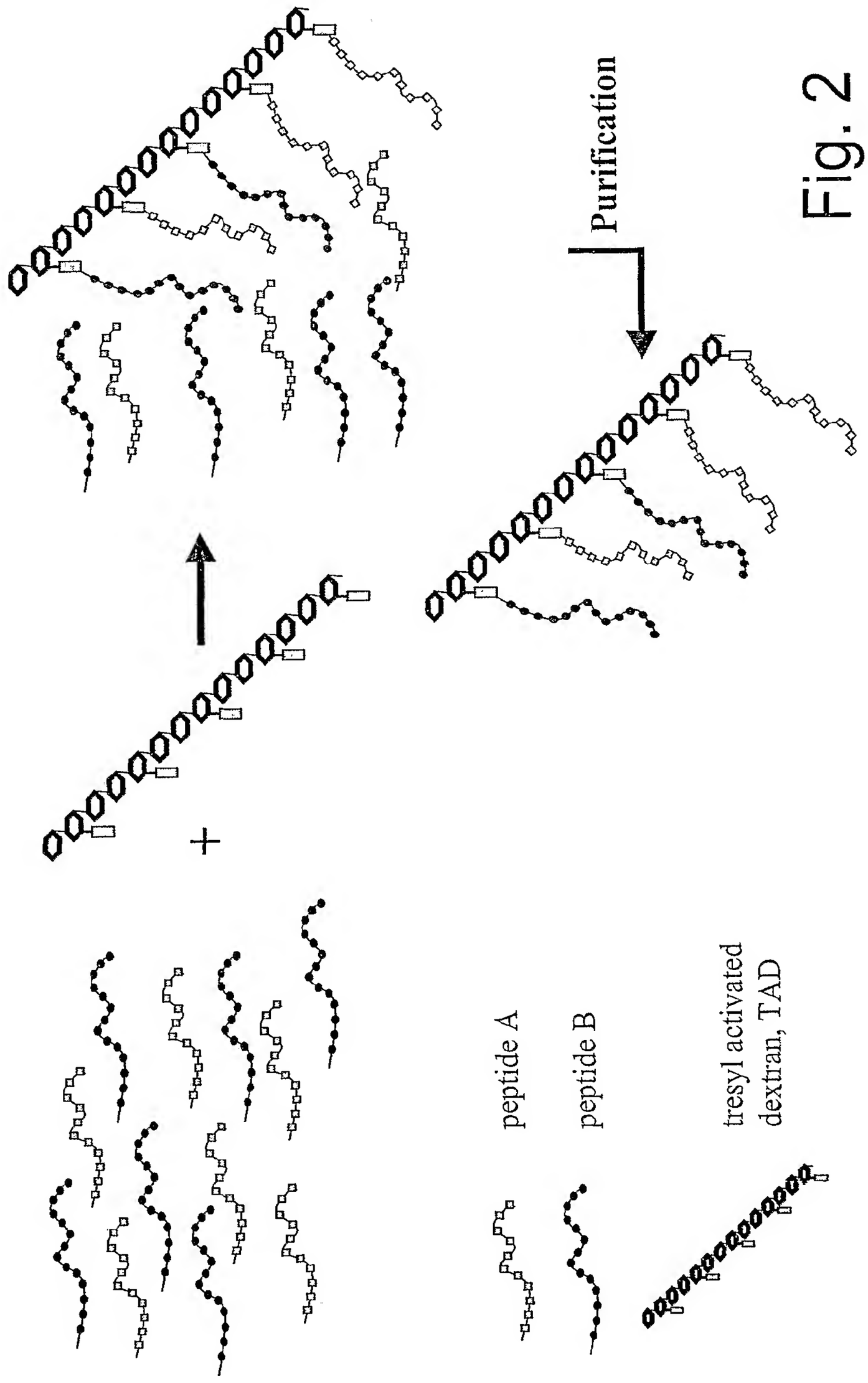
Fig. 1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peptide B
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Fig. 2

SEQUENCE LISTING

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<220>
<221> CDS
<222> (1)..(63)
<223> DNA encoding P30 epitope

<400> 5
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Phe Asn Asn Phe Thr Val Ser Phe Trp Leu Arg Val Pro Lys Val Ser
1 5 10 15

gct agc cac ctg gaa 63
Ala Ser His Leu Glu
20

<210> 6
<211> 21
<212> PRT
<213> Clostridium tetani

<400> 6
Phe Asn Asn Phe Thr Val Ser Phe Trp Leu Arg Val Pro Lys Val Ser
1 5 10 15

Ala Ser His Leu Glu
20

<210> 7
<211> 21
<212> DNA
<213> Synthetic
<223> Synthetic PCR primer

<400> 7
caactcagct tcctttcggg c 21

<210> 8

<211> 21
<212> DNA
<213> Synthetic
<223> Synthetic PCR primer

<400> 8
agatctcgat cccgcgaaat t 21

<210> 9
<211> 135
<212> DNA
<213> Synthetic
<223> Synthetic PCR primer

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ttcgcagaag atgttggttc caacaaaggt gcaatcatcg gtctgatggt tggcggtgtt 120
gttatcgcga cctag 135

<210> 10
<211> 31
<212> DNA
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<400> 10
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<210> 11
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<212> DNA
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<212> DNA
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<400> 12
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gtcgcgataa caacaccgcc aacc 84

<210> 13
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<212> DNA
<213> Synthetic
<223> Synthetic PCR primer

<400> 13
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cgcgagccac ctggaagatg cagaattccg tcacgactcc g 101

<210> 14

<211> 172
<212> DNA
<213> Synthetic
<223> Synthetic PCR primer

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cctttgttgg aaccaacatc ttctgcgaag aaaaccagtt tctggtggtg aacttcgtaa 120
ccggagtcgt gacggaactc tgcatccagc tcggtgatac cgatgaattt gg 172

<210> 15
<211> 30
<212> DNA
<213> Synthetic
<223> Synthetic PCR primer

<400> 15
ctggaagatg cagagttccg tcacgactcc 30

<210> 16
<211> 35
<212> DNA
<213> Synthetic
<223> Synthetic PCR primer

<400> 16
gcgccggatc cttcaacaac ttcaccgtta gcttc 35

<210> 17
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<213> Synthetic
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<400> 17
Ala Lys Phe Val Ala Ala Trp Thr Leu Lys Ala Ala Ala
1 5 10